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HUGH CUMING'S LETTERS TO SIR WILLIAM J. HOOKER

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ONE PLATE

The letters from Mr. Hugh Cuming to Dr. (later Sir) William Jackson Hooker, preserved in the latter's correspondence at the Royal Botanic Gardens, Kew, England, are thirty-three in number. They were written between the dates December 6, 1831, and January 21, 1858, some from London previous to Cuming's departure for the Philippine Islands, a few during his sojourn in the Islands, and the remainder after his return to England in June, 1840. These letters form a very human document and are in themselves an interesting commentary on the vicissitudes in the life of a field naturalist, both in the field and at home. Copies of these interesting letters were kindly prepared for me in 1910 by Sir David Prain, then director of the Royal Gardens, Kew. They are published here with the permission of Dr. A. W. Hill, the present director of the institution.

It is unfortunate that Cuming did not more fully describe his own experiences in these letters, but this may be accounted for by the fact that he was too busily engaged in collecting and preparing natural-history material in a very rich and previously unexplored field to take the time to write up his observations and experiences. A perusal of two letters, an undated one written from Thavies Inn, London, the latter part of 1840 or the early part of 1841 (p. 172), the other under date of May 25, 1841 (p. 173), clearly indicate that he did write an account of his experiences. The fate of this account is revealed in Cuming's letter of May 25, 1841, it falling in the category of

rejected manuscripts. Cuming's journal is probably no longer extant, but if it could be located it would to-day undoubtedly prove to be of very great interest to residents of the Philippine Archipelago, as well as to naturalists who are interested in studying the fauna and flora of the Islands. That he must have been a keen observer and that he must have had many interesting as well as some disconcerting experiences during the several years he was in the Philippines, owing to the primitive conditions then existing there, goes without saying.

We learn from Cuming's letters that he left England February 26, 1836, and returned June 5, 1840. He apparently reached Manila in October, 1836, as by November 10, 1836, he was busily engaged in prosecuting field work at Calauan, Laguna Province, Luzon. He left Manila on his return trip in November, 1839. In approximately three years, which he devoted to natural-history exploration in the Philippines, he prosecuted field work in most of the provinces in Luzon and visited nearly all of the larger islands in the Archipelago except Palawan, as well as some of the smaller ones.

As a collector, Cuming was primarily interested in securing conchological material, but his personal interests did not deter him from making more general collections such as mammals, birds, reptiles, insects, and crustaceans, as well as botanical material in most groups of plants. The only major fields he seems to have ignored are the marine and fresh-water fishes and representatives of those lower groups which in general are classed under the term marine invertebrates. This is probably explained by the fact that none of his associates in England requested him to secure such material. It is evident from his letters written before leaving England that he consulted numerous individuals previous to his departure with the view to determining what his friends and associates desired him to collect, and that when he was once in the field he diligently attempted to secure the material they desired in addition to conchological material, the securing of which was the prime object of his expedition to the Philippines.

Cuming's large collections of dried botanical material formed the essential basis of our knowledge of the rich flora of the Philippine Archipelago up to the beginning of the present century; in fact, in extent his collections have been surpassed by those of but very few individuals who have worked in this field during the past eighty years. Probably the collections made by no single individual can be considered as exceeding in value

those made by Cuming, in view of the fact that such a high percentage of his specimens became the types of new species. It is evident from an examination of the list of Cuming's plants that he followed Hooker's [1] advice and ignored those species growing in the vicinity of towns and along the seashore, and confined his field work very largely to the forested regions. The forests of the Philippines present a very high percentage of endemic species, while the vegetation of the settled areas and the open country is for the most part made up of very widely distributed forms; this statement applies also to all parts of the Malay Archipelago, and it is interesting to note that this fact was appreciated by Sir William J. Hooker, although he never personally visited the region. Cuming collected material representing not only the flowering plants and ferns, but also algæ, fungi, hepatics, lichens, and mosses. In addition to the dried material prepared by him he also sent extensive collections of living orchids to England.

Those familiar with the Philippine flora are impressed by the fact that very many common and widely distributed species are not represented in the Cuming collection. This is explained in part by the fact that to a considerable degree he ignored the littoral species and those growing in the open settled areas at low altitudes. The absence of many of the common and widely distributed endemic species characteristic of the forested areas is explained by the loss of a case of specimens referred to in his letter of November 18, 1838 (p. 168), and to the destruction of most of the material in seven cases by water, referred to in his letter of August 1, 1840 (p. 170).

The extent and value of the great collection of conchological material assembled by Mr. Cuming is well indicated by the following quotations from Sir Richard Owen's statement prepared in 1848.[2] This was addressed by him as Keeper of the Natural History Department of the British Museum to Dean Buckland, a trustee of the British Museum, when the collection was offered for sale but was not then accepted by that institution. The collection was greatly increased in the number of species represented, in the period of seventeen years that elapsed between this date and Mr. Cuming's death in 1865. It was purchased by the British Museum in 1866.

[1] See letter dated December 18, 1835, p. 166.

[2] Melvill, J. C., Journ. Conchol. 8 (1895) 65–68; see also Owen, R., Life of Sir Richard Owen 1 (1894) 313 et seq.

I may briefly state that this collection, as now offered to the British Museum, contains upwards of 19,000 species and varieties of shells, represented by about 60,000 specimens; and that not only is every specimen entire, but choice and perfect of its kind, as respects form, texture, colour, and other characters that give it value in the eyes of the shell-collector.

As I can affirm from my personal knowledge, and from authentic sources of information, that no public collection in Europe possesses one-half the number of species of shells that are now in the Cumingian collection, you may judge of the vast proportion of rarities and unique specimens possessed by Mr. Cuming. It is this which has given him for some years past the command, so to speak, of all the conchological cabinets in Europe. He is better known and respected, and his labours more truly and generally appreciated in any city or town in Europe having a public natural history museum than in busy London. Mr. Cuming in his annual visits to the continent carries with him the inferior duplicates of his rarities, representing species with the sight of which the eyes of the foreign naturalist are gladdened for the first time. They open to him their treasures in return, and from most of the collections of Europe Mr. Cuming has borne away the prized species or specimens in exchange for the still rarer and more valuable shells which his abundance has enabled him to offer without detriment to his own stores.

The mode in which Mr. Cuming has obtained this conchological wealth is as moral and exemplary as the result is important and marvellous, considered as the work of one individual. Not restricting his pursuit to the stores and shops of the curiosity-mongers of our seaports, or depending on casual opportunities of obtaining rarities by purchase, he has devoted more than thirty of the best years of his life to arduous and hazardous personal exertion, dredging, diving, working, wandering under the Equator and through the Tropics, the Temperate Zones, both north and south, in the Atlantic, in the Pacific, in the Indian Ocean, and in the islands of its rich Archipelago—in the labour of obtaining from native seas, shores, lakes, rivers, and forests, the marine, fluviatile, and terrestrial mollusca, 60,000 of whose shelly skeletons, external and internal, are accumulated in orderly series in the cabinets with which the floors of his house now groan. I never think of the casualities to which such a collection in such a place is subject without a shudder!..... Perhaps one of the most striking points in the estimate of the scientific value of an extensive collection like Mr. Cuming's arises out of its relation to the present active pursuit of geology as an indispensable instrument to the determination of fossil shells. No one can give higher sanction than yourself to any expression of the importance of well-determined fossils, and especially shells, to a right knowledge of the relative age and position of the strata in which they were embedded; and the geologist's confidence in results based upon fossil conchology must be in the ratio of the extent of this comparison with recent shells that have been gone through in the determination of the fossil shells, and especially before a species is pronounced to be extinct.

This, however, is but one of its scientific uses. From the period when the Atlantic, American, and Polynesian departments of the Cumingian collection reached England, in 1831, scientific conchologists have there found subjects without intermission for their descriptions, and the novel-

ties were far from being exhausted when Mr. Cuming, having undertaken a third exploring voyage, returned in 1840 from Manila, stored with the conchological riches of the Indian Ocean, which have subsequently kept the pens of competent describers of new genera and species actively at work, and will supply them for years to come. Thus the Cumingian Collection has directly advanced the science of conchology in an unexampled degree, and possesses the same peculiar claims upon the Government as custodians of the National collection here which Linnaeus' Herbarium did upon the Swedish State. Mr. Cuming's collection contains, for example, the originals from which many hundred new species have been described in the scientific periodicals or systematic works published since its arrival in this country.

Any doubt that may arise through the incompleteness or obscurity of the description, or from the inaptitude of the student, may be decided at once by reference to the original specimens. These "types of the species" become, therefore, an instrument of great importance to the progress of the science in the country in which they are preserved and made accessible. Delay in securing for the nation the Cumingian types of new species of shells may involve the necessity of crossing the Atlantic in order to compare and verify the descriptions and synonyms of Broderip, Sowerby, Gray, Reeve, and other eminent conchologists.

The value of a shell, as of a jewel, depends much upon its rarity, and is to that extent artificial. The *Concha unica*, which today commands the sum of twenty pounds, shall, next week, when a score of specimens have come into the market, fall in price to as many shillings. Still, the commonest exotic shell, if it be perfect and well coloured, and taken from a living mollusk, as is the case with the Cumingian collection, from which "dead" shells have been strictly excluded, finds its market.

I am given to understand, by competent authorities, that the sum of £6,000 asked by Mr. Cuming in 1846 does not exceed two-thirds of the most moderate estimate of the present market value of his subsequently augmented collection.

That ten times that sum would not bring together such a series as Mr. Cuming has offered to the British Museum, I do firmly believe, from a knowledge of the peculiar tact in discovering and collecting, the hardy endurance of the attendant fatigue under deadly climes and influence, and the undaunted courage in encountering the adverse elements, and braving the opposition of the savage inhabitants of seldom-visited isles, which have conduced and concurred to crown the labours of Mr. Cuming with a success of which his unrivalled collection is a fitting monument, and of which science, and, let us hope, its cultivators in his native country more particularly, will long continue to reap the benefits.

Mr. W. J. Broderip [3] briefly summarizes the field work prosecuted by Cuming in the Philippines; his data are given on page 158. As noted in this account, Cuming was a pioneer in attaching exact locality data to the shells collected by him. In

[3] Description of shells collected in the Philippine Islands by Hugh Cuming, Esq., Proc. Zool. Soc. London 8 (1840) 83–84; reprinted in Ann. & Mag. Nat. Hist. 7 (1841) 226–227.

a sense, also, he was a pioneer in attaching numbers to the botanical material distributed by him, for his extensive *exsiccata* was apparently one of the first large collections of botanical material so distributed, a custom that soon became almost universal.

Mr. Cuming, the fruits of whose western voyage are so well known, left England on the 26th of February 1836: he proceeded to the Philippine Islands, by the permission of the Queen Regent of Spain and aided by powerful recommendations from her government, which opened to him the interior of the islands, and caused him to be received with a noble hospitality, equalled only by the warm interest which facilitated his pursuits wherever he arrived and made himself known.

Mr. Cuming visited the whole group. His longest stay was in the Island of Luzon, fifteen provinces of which were well ransacked by him. In the islands Mindoro, Negros, Panay, Siquijod [Siquijor], Zebu [Cebu], Bohol, Camiguing [Camiguin de Misamis], Mindanao, Leyte, Samar, Capul, Ticao, Masbate, Burias, Temple, Marinduque, Maracavan [Maricaban], and Romblon, he reaped a fine harvest. He left the Philippines in November, 1839, proceeded thence to Sincapore and Malacca, and returned to England in June, 1840, bringing with him, besides the living animals which he has liberally presented to this Society, a grand collection of zoological and botanical specimens, including more than three thousand species and varieties of shells, the greater part of which appear to be new to science, and among them are several new genera. The smaller islands were particularly rich in the pulmoniferous mollusca, which were found by Mr. Cuming principally in deep forests. We commence a notice of the labours of this active and zealous collector, with an attempt to describe a few of these terrestrial species. Mr. G. B. Sowerby, who liberally gives up his valuable time to assist in laying before the public the novelties of this part of the collection, will also begin his share of the task, by describing another branch of the same numerous family; and it is intended to submit descriptions to the Society from time to time till the whole of Mr. Cuming's stores are exhausted.

Before, however, we commence our task, I must, in justice to him who has placed the materials in our hands, observe, that, to say nothing of the variety of new forms which he has been the means of bringing to light, those who cultivate this branch of zoology so highly interesting to the geologist, as well as the physiologist, owe him a large debt of gratitude, for information on a point of no small zoological importance. It is not very long since, that the localities ascribed to shells could in very few instances be depended upon. The cupidity of dealers, some years ago, not unfrequently prompted them wilfully to deceive those who gave extravagant prices for new shells on this point, and carelessness was generally the order of the day. Mr. Cuming, by his accurate notes, and the open publication of the places where every one of the multitudinous species and varieties collected by him was found, has mainly assisted in making a complete revolution in this department of the science, and has done more towards giving us data for the geographical distribution of the testaceous mollusca than any person who has yet lived.

On the occasion of Cuming's death several biographical notices were published, the most extensive one that I have seen being that reproduced below.[4]

Hugh Cuming, Esq., F. L. S., died on the 10th of August, 1865. He was born at West Alvington, near Kingsbridge, in Devonshire, on the 14th of February, 1791. Remarkable even as a child for his love of plants and shells, the latter taste more especially was largely fostered and developed under the patronage of Colonel Montagu, who resided in the neighborhood.

Apprenticed to a sail-maker, he was necessarily brought into contact with seafaring men; and in 1819 he made a voyage to South America, and settled at Valparaiso. Here his passion for collecting shells found ample field for its gratification, and was greatly stimulated by the English Consul, Mr. Nugent, and by several officers of the British Navy, and especially by those in the surveying ships under Captains King and Fitzroy. In fact, in 1826, he gave up his business in order wholly to devote himself to his favorite pursuit. With this object he built a yacht, expressly fitted for the collection and stowage of objects of natural history, and a cruise of upwards of twelve months among the islands of the South Pacific amply rewarded him for his toils in dredging and collecting by sea and on shore. On his return to Valparaiso he prepared for a voyage of greater extent, on which he started under peculiar advantages. The Chilian Government granted him the privilege of anchoring in its ports free of charges, and of purchasing stores free of duty; and he was also furnished with letters to the authorities of all the states he visited. After two years spent in exploring the coast from the Island of Chiloe to the Gulf of Conchagua, dredging in all the bays and inlets, searching among the rocks and stones at low water, and inland in the plains, river-banks, and forests, Mr. Cuming returned to England with an enormous accumulation of natural history objects of all kinds. The most important part, however, was the conchological. In 1835 Mr. Cuming undertook a new expedition to the Philippine Islands, a region rich in natural productions, and but little explored, and where his familiar knowledge of the Spanish language and manners would be of great advantage. Here, although dredgings on the shores were not neglected, his attention was more particularly directed to the woods and forests, where he reaped a most abundant harvest of plants, and collected such an immense and magnificent series of land-shells as had never before rewarded the exertions of a collector. In every place Mr. Cuming was the guest of the priest, always the chief personage in the interior of these islands, and by whom he was always assisted in every imaginable way. He was also thus enabled to obtain what was of still greater importance, the services of the children educated in the public schools, and numbering

[4] Hugh Cuming, Esq., F. L. S., Journ. Linn. Soc. Zool. 9 (1868) LVII–LIX. See also Journ. Bot. 3 (1865) 325–326; Athenaeum (1865) 247–248; Gent. Mag. III 19 (1865) 517–519; Gard. Chron. (1865) 823–824; Dict. Nat. Biogr. 13 (1888) 295–296; Vidal Phanerogamae Cumingianae Philippinarum (1885) VII–X.

in some places as many as 400 or 500. By the aid of these sharp-eyed auxiliaries, shells which gladdened his eyes by their novelty and exceeding beauty were daily brought to him in prodigious numbers.

After four years spent among these islands [that is, an absence of four years from England, three of which were spent in the Philippines], and in short visits to Malacca, Singapore, and St. Helena, Mr. Cuming returned to England with the richest booty ever collected by a single man. His dried plants, which numbered 130,000 specimens, were immediately distributed, as well as his living Orchids, which were numerous and of great beauty. Large numbers of Birds and Reptiles, Quadrupeds and Insects, were added to museums at home and abroad. But the shells formed by far the most important part of his collections. Before leaving England he had brought together from his own American collections and elsewhere the largest and most valuable collection then in existence. By his vast Philippine collections this was increased to an enormous extent; and during the twenty-five years that have since elapsed he was untiringly engaged in its arrangement, completion, and description by various conchologists. It is stated to have contained not less than 30,000 species and varieties, and in most cases several specimens of each.

From time to time he disposed of his duplicate specimens to various public and private collections, and always took pleasure in acknowledging that his expenses and labours had been amply repaid.

"The great object of my ambition," he said in 1858, "is to place my collection in the British Museum that it may be accessible to all the scientific world, and where it would afford to the public eye a striking example of what has been done by the personal industry and means of one man."

This worthy object has been obtained, and the British Museum has since his death purchased this unrivalled collection, and placed it where its founder's wishes desired it to be.

The Linnaean Society, also, owes a special debt of gratitude to Mr. Cuming, who several years since presented to our Library his extensive collection of Conchological Works, into possession of which we have now entered.

Mr. J. C. Melvill [5] in 1895 published a short appreciation of Mr. Cuming's life and accomplishments from which the photograph illustrating this paper is reproduced. This article is supplemented by another in the same periodical by Mr. E. L. Layard,[6] on some personal recollections of Mr. Cuming. Mr. Layard's statements, "I do not think that he [Cuming] could do more than write his name" and "I have also said that I do not think that he [Cuming] could write," are refuted by Cuming's own letters. Of the thirty-three letters written by Mr. Cuming between December 6, 1831, and January 21, 1858, thirty-one were written by Cuming himself, two dated January 16 and

[5] An epitome of the life of the late Hugh Cuming, F. L. S., C. M. Z. S., etc., Journ. Conchol. 8 (1895) 59–70, plate.

[6] Op. cit. 71–75.

21, 1858, having been written by his daughter and signed by him. His handwriting is good and the few errors in spelling are probably due more to hasty writing than to ignorance. With his limitations as to education, it is all the more remarkable that Mr. Cuming was able to accomplish so much in the field of natural history, and especially in building up his enormous private collection of conchological material.

A bibliography of the papers based wholly or in part on Philippine collections made by Mr. Cuming would include many hundred titles, as the fields of general zoölogy, including conchology, entomology, ornithology, herpetology, and mammalogy would have to be covered, as well as that of systematic botany of both the phanerogams and the cryptogams. In practically all monographic treatments of genera and families which have been issued since 1840, so far as the numerous groups are represented in the great Cuming collections, his material is repeatedly cited and of necessity must continue to be cited because of its historical significance. A partial bibliography of papers based wholly or in large part on the Philippine material collected by Mr. Cuming is appended to this paper. No attempt has been made to make this bibliography complete, my object in compiling it being merely to give some graphic idea of the extent and scientific value of the collections assembled by this one man through his own initiative and on his own resources. In general no titles have been included where Cuming's material is merely mentioned. If this had been done, the list in botany alone would exceed six hundred titles.

A perusal of the following letters indicates that Cuming's education was deficient, yet his letters show that he was reasonably well educated. It is evident that he has attained more lasting fame than untold thousands of highly educated men; and it is also clear that his fame is more firmly established than is that of some authors of ponderous tomes and of numerous papers. Mr. Cuming apparently subordinated his own desires to a very large degree to the building up of his conchological collection. It is clear from his undated letter written from Thavies Inn (p. 172), and the following one written under date of May 25, 1841 (p. 173), that he had no illusions regarding his ability as an author. Would not some of our biological literature be of distinctly higher grade if more individuals had followed Cuming's plan of permitting and even encouraging others, presumably better equipped, to publish the results obtained by their field work?

Mr. Cuming was elected a Fellow of the Linnaean Society on May 1, 1832, and so remained until his death. His election was based not upon any data published by him, but apparently on the value of his services to the biological sciences as a collector, and further because of the fact that through his own efforts and on his own resources he built up the largest and most valuable conchological collection ever assembled by any one man or institution up to the time of his death. He personally published very little and most of the several references listed below are merely extracts from letters written by him, or references to letters received from him.

CUMING, H.

On the earthquake at Valparaiso in 1822. Proc. Geol. Soc. 2 (1838) 213–214.

On the earthquake in Chile, November 19th, 1822. Trans. Geol. Soc. 5 (1840) 263–265.

On the habits of some species of mammalia from the Philippine Islands. Proc. Zool. Soc. London 6 (1838) 66–68.

(Notice of) a letter dated Manila, December 24, 1836, accompanying a large box of skins of birds and quadripeds. Proc. Zool. Soc. London 5 (1837) 70.

(Notice of) a letter dated Manila, November 16, 1837, forwarding a collection of 295 birds and 12 quadripeds. Proc. Zool. Soc. London 7 (1839) 93.

(Notice of) a letter dated Manila, November 5, 1839, referring to the shipment of some cases of specimens. Proc. Zool. Soc. London 8 (1840) 33.

(Notice of) an exhibition of specimens. Proc. Zool. Soc. London 8 (1840) 62.

Mr. Melvill [7] lists the conchological genus *Cumingia* Sowerby and one hundred fifty-two species of mollusca dedicated by various authors to Hugh Cuming. In other zoölogical groups I find two birds, one turtle, one snake, five lizards, one mammal, and several insects named by various authors in honor of Mr. Cuming from his Philippine collections. In botany the genera *Cumingia* G. Don, based on South American material [=*Conanthera* Ruiz and Pav.], and *Cumingia* Vidal, based on Philippine material [=*Camptostemon* Masters], have been dedicated to him, while approximately one hundred forty species of plants have been described from his Philippine collections alone with specific names derived from that of this remarkable collector.

Of the thirty-three letters written to Sir William Jackson Hooker by Cuming, sixteen are reproduced below, as the re-

[7] Journ. Conchol. 8 (1895) 69, 70.

maining ones do not appertain to his Philippine experiences but refer to other matters.

79, CHARLOTTE ST., FITZROY SQ.,
London, Nov. 24, 1834.

DEAR SIR,

A Friend of mine having just returned from South America has made me a present of two Rock plants. From their appearance I think they are in Fruit. If they are worth your acceptance I shall be most happy as a Friend of yours informed me you had not one that was in Flower. Mr. Hunneman has kindly promised to forward them to you. I have been informed you have published a third part of my plants. If that is correct I shall feel most oblidged to you for it. Although not a Botanist I feel highly interested in possessing the work complete particularly as you have done me so much Honour in the kind manner you have there spoken of me. I have not had a letter from Mr. Brydges since I wrote you last. He is in the place I then spoke of near the Andes halfway betwixt Santiago and Conception. He ought there to make a fine collection. My Friend informs me Mr. Matthews left him some time since to pass the Andes from the pass near Truxillo and would collect on the Banks of the Maranan. He gave my Friend a few Ferns the like I never before saw they are very beautifull.

I shall feel most oblidged if you could gain any information in Glasgow or Grenock respecting Manilla and the Phillipine Islands, as it respects the Climate, State of Society amongst the lower classes and the Aborigines, or any information of the Civil Government towards strangers particularly those who might visit the place in Scientific Pursuits. At the same time please let me know if there has been any collectors of Natural History in those Islands or Botanists. I am still of a roving mind and should I gain anything like a satisfactory account of the place I have a great mind to pay it a visit for Two or Three years. Perhaps I might be able to render you some little service if it should not have been visited by a Botanist. From what I have learned here, nothing is hardly known respecting those Islands, all the shells from there are most beautifull and in England extremely rare. As I have not opened my mind to any one here, I beg you will not mention the subject to any person whatever as it would be more than a year before I could be ready to start, therefore I would not wish it to be known what my intentions where for the present; having received many kindnesses from your hands I hope I do not intrude by soliciting the above favour. Should I go I can only say you should have the preferance as before; when it is convenient I shall be most happy to receive an answer. If favourable I then will think about it in earnest.

I am Dear Sir
Most Oblid
to command
[Signed] H. CUMING

Dr. HOOKER,
Glassgow.

LONDON, *July 6, 1835.*

MY DEAR SIR,

I trust you will not think me ungrateful in not answering your most kind interesting letter of Decr. last, where you offered your Friendship If I went to India. I have duly matured upon a Collecting Voyage to that part of the World and would have written in answer long since If I had been sure I should have permission of the Spanish Court to visit the Philippine Islands as that place appears to be least known of any civilised part. I have now the promise of the Grant from the Spanish Ambassador through the Influence of Earl Derby and I trust ere long to have it in my possession. Accept my best thanks for your kind offers of letters of introduction. I shall feel greatly oblidged to you for them to any persons who may have interest in the Straits of Malacca, Sincapore, Penang, Canton, Java and Manilla as I think I shall visit all the above places and at the same time I shall be most proud to receive from your hands any instructions as it respects collecting of Plants &c. which you may think upon that I may be able to render you all and every Service that will lay in my power to execute; and at the same time you will confer a great favour by procuring for me as many Gentlemen who will be willing to take Collections of Plants from me on or befor my return at the same price as before. I have spoken to Mr. Brown and will also speak to Dr. Lindley and Mr. Bentham.[8] Perhaps you may be acquainted with some Gentlemen in London or this part of the kingdom who would be willing to add to their stores. If you would be pleased to give me their Names I will do myself the pleasure of waiting upon them or writing saying I have been recommended by you to make known my intentions &c.

I intend to leave England for Hamburg Copenhagen and Berlin on the 1st of August and will return to Town by the 1st of October and will finally leave England for the Indian seas by the first vessell after the New Year. I have to repeat how happy I shall be to receive any instructions, hints, and Letters of introductions from your hands and in return I will make the most complete Flora of those parts which I may visit that circumstances will admit of such as specimens, Fruits, and Woods. Realy I fear I am giving you a great deal of Trouble, but well knowing your great love for the Vegetable productions of all the World prompts me to ask the above favours in hopes of being able to make something like a return. I shall feel oblidged by an answer before the 1st of August saying what your Ideas are upon the subject perhaps you will not have time for the other subjects mentioned and there is not any hurry October will be time enough for them.

[Unsigned]

LONDON *July Six 1835*
Dr. HOOKER
Regius Professor Botany
Glasgow.

[8] Robert Brown, 1773–1758; John Lindley, 1799–1865; George Bentham, 1800–1884.—E. D. M.

LONDON *July 17—1835.*

MY DEAR SIR,

I had the pleasure to receive yours of the 9th and feel much oblidged for the many usefull hints you have given me therein. I can assure you nothing would induce me to have any thing belonging to me advertized. I merely intended, when I did myself the pleasure of writing you last to know if those Gentlemen who took Collections of my Chillian Collection would like to have from me on my return from the East. If I was to ask the public for Subscriptions, they would think I was in want of Cash. That I am proud to say is not the case in any degree beforehand. Under the above circumstances I should feel oblidged by your merely mentioning to your Botanical Friends when you meet them that I am going or gone to the Phillipine Islands and nothing more.

I have had a Letter from Mr. Fielding[9] of Lancaster requesting me to consider him a Subscriber. I have answered the Gentleman and he is put down the 7th on the List. I have done myself the pleasure to place your name on the Top of it. On my return from the Continent I will write you again by that time I shall be able to say what time I shall leave. As it respects the specimens I trust they will be better than the last. I will bring them large enough even to please Mr. Lambert.[10]

I am Dear Sir

Yours most sincerely

[Signed] H. CUMING

A few days since I had the pleasure to be introduced to a Friend of yours Mr. Harvey[11] of Limerick. He is a Conchologist as well as a Botanist. I gave him every information and written instructions how to collect shells and plants, the mode of packing them, &c. I found a most perfect Gentleman and most grateful for what Information I could give him. If I should call at the Cape he tells me I shall find a hearty welcome. I may touch at the Mauritius. I intend to visit Sincapore Malacca and Penang. At Malacca or near it is a most particular Fern of which there is but a small imperfect specimen in England. I will visit that place for that Fern alone. Mr. Brown has given me the above information. Do you know any Merchants at Glasgow who have a House at Manilla if so it would be a mutual advantage to both.

Yours most sincerely

[Signed] H. CUMING

LONDON: *July nineteen 1835*
Dr. HOOKER
Reg. Prof. Botany
Glasgow

LONDON. *Oct. 7th 1835*

MY DEAR SIR,

I had the pleasure to find your letter of the 28th of Sept. laying at my house on my return from the Continent for which I am much oblidged.

[9] H. B. Fielding, died 1851.—E. D. M.
[10] A. B. Lambert, 1761–1842.—E. D. M.
[11] W. H. Harvey, 1811–1866.—E. D. M.

When at Berlin Dr. Klotzsch gave me a parcel of plants for you which I have delivered to Mr. Hunneman who will forward them by Mr. M'Nab of Edinburgh on Saturday next with a specimen of an Aristolochia which is now in Flower at the Bot. Garden, Berlin, Dr. K. thence inclosed. In answer to yours respecting the places I intend to visit during my absence I will say Penang, Malacca, Sincapore and the Phillipines Islands to be the ostensible object I have hitherto in view but should vessell offer it is more than probable I shall also visit Timor Borneo and some of the adjacent Islands. Therefore I shall feel most particularly oblidged by all the Letters of Introduction you can procure for me for the Eastern Seas, not forgetting Macao [12] as it is probable I may call there.

I have made up my mind to quit London by the first *ship* after the New Year as I intend to be quite ready by the last day of the present year. You will confer a favour when you send me the Letters to give me a list, with particulars what you would wish me to collect besides the usual plants for you or any of your Friends. Mr. Brown, Mr. Stokes and some others have requested me to procure them things I should never have thought of and perhaps you may think of some things also. I shall pay due attention to the Mosses and Fuci. Some persons in Germany have also requested me to collect Fuci and Fungi. I will do my best endeavor to give satisfaction to all parties taking due care to give you a preference in everything you request me to collect. I have told them all I shall do so for Auld Lang Synge. I intend to collect seeds. Perhaps some of your Friends may like to have a collection

I hope the above will meet your approbation.

I am Dear Sir
Yours most Gratefull
to Command
[Signed] H. CUMING

Dr. HOOKER,
Regius Professor of Botany
Glasgow.

LONDON *Dec. 18, 1835.*

MY DEAR SIR,

Your most valuable packet came safe to hand, for which be pleased to accept my most sincere thanks and I trust your kind intentions will not be thrown away. Mr. Stokes had a few days before the arrival of your letters introduced me to Mr. Crawford [13] who has given me several letters to his Friends in India. I did myself the pleasure to write Mr. C. a note and inclosed yours to Him. Mr. Millet is living some place in Hampshire and having many letters to India perhaps it will not be necessary to trouble him on the subject. I feel most oblidged by your friendly hints and I will do all I can to perform the utmost of your wishes. Whenever an opportunity offers I will do myself the pleasure of informing you of my progress in the various branches of Natural History. Mr. Stokes has promised me letters for Macao. I expect to sail from Liver-

[12] These letters antedate the establishment of the Hongkong colony; Macao was then an important port.—E. D. M.

[13] Probably J. Crawford, orientalist, 1783–1868.—E. D. M.

pool on or about the 15th for Batavia Sincapore and Manilla. You say I must not collect plants near the Sea Coasts. I shall not be able to refrain from it knowing now a little of the plants so that I won't collect the same at every place I meet for I am of an opinion I may get plants on the Sea Coasts that has escaped the Eyes of all others. I did so in Chili and trust to do the same in the East and when I cannot collect plants with seeds and flowers at the same time I intend to collect them separate so that you shall be able to make them out. I have orders for all kinds of seeds with Branch &c.

If any vessell should sail from your port to Manilla for the next two years I should be most happy to hear from you it would afford me great pleasure to know what might occur in the Scientific World.

In expectation of having the best opportunity of a Collector and the Zeal of [an enthusiast? letter torn] during my voyage I shall be able to make you a return for the many favours received by bringing you a large Collection of new plants worthy of your notice and the first Choice.

I am Dear Sir
Yours most sincerely
Most Gratefull
[Signed] H. CUMING.

To Dr. HOOKER
Reg. Prof. Botany
Glasgow.

CALAGUAN, PROVINCE OF LAGUNA DE BAHIA
[that is, Calauan, Laguna Province]
LUZON *Nov. 10, 1836*

DEAR SIR,

Having the Honour to make the acquaintance of your Friend Mr. Maartens at this place I have done myself the pleasure of forwarding by him five specimens of plants to show you and my Friends that I am living and well in a perfect paradise having collected on this Estate alone 500 species of plants in Six Weeks besides innumerable species of Insects Shells and Reptiles. If convenient I should feel oblidged by your showing Messrs. Loddiges the Orchideae as I shall send him in Jan. next some living specimens. I presume the Ferns are new, to me they have given great pleasure in collecting them. I have taken nearly 50 species from this spot alone principally large ones.

My best respects to my Friends of the Linnean and say I shall be most happy to present an entire Collection of plants that I may collect in those Islands to the Society on my return.

I am Dear Sir
Yours Most Truly
[Signed] H. CUMING.

MANILA *Dec. 24, 36.*

DEAR SIR,

I have the pleasure to inform you of my arrival at this place on the 24th of July last just as the Rainy Season had set in therefore I could not make any excursions in the Country untill the end of Sept. then I left this place for the Hacienda of Calaguan [Calauan] in the center of

Luzon where I remained untill the 15th of this Month making excursions to the Woods and Mountains in the Neighborhood and I trust my Labours will meet your approbation having collected about 1150 species of all classes since my arrival and I am proud to say nearly 1/10 are Ferns of the most beautifull forms you can conceive. Two species are Trees and one a perfect shrub throwing its branches like the Fir, and all in Flower except two or three species. I have also many species of Mosses but not many Flowering Shrubs, like those of Chili in form. Many Trees give splendid Flowers but their time is principally in March, April and May, but many of them flower twice a year. I have collected upwards of 50 Species of Orchideae but not many in Flower and of the Fungi 125 Species.

I am now preparing for a Voyage to the Southern Islands viz. Zebu, Negros Leyte and Mindanao, and if I am not made a Prisoner by the Malays I trust I shall on my return in July next be able to give you as equally good an account of myself. As yet I have not made any excursions on the Sea Coast but yet I have collected 250 Species of Shells; Insects, Reptiles and Crustaceous subjects have had their due, and I have even surprised myself in what I have done.

My reception from the Govt. has been most flattering every facility has been offer'd and afforded and the Hospitality of the Resident Spaniards is far from my expectations although I experienced much of it in South America. During the time I was at Calaguan [Calauan] I well tried my Constitution amongst the Woods, Mountains, Marshes and Rivers some days out all the day in the rain. As yet I have not had a moment's pain except from Venomous Insects &c. which are abundant and what is more strange Calaguan [Calauan] is the most unhealthy spot in the Island therefore I trust the Climate will not injure my Health. Should anything happen to me that I should Die I have order'd all my Botanical Collection should be sent to your care and you to select out a perfect Collection with duplicates where necessary, for your own use and that you would be pleased to dispose of the remainder to those who would wish to take them on the former Terms *for the benefit of my Estate.* I should be most happy to hear from [you] particularly if I can be of any further service to you during my residence here.

I am Dear Sir
Yours Most Sincerely
[Signed] H. CUMING

To
Sir WILLIAM JACKSON HOOKER, Knt.
Regius Professor of Botany
Glasgow.

MANILA *Nov. 18, 1838.*

MY DEAR SIR,

I did myself the pleasure of writing you in Dec. 1836, and also in Nov. 1837, [? dated Nov. 10, 1836] and up to the present date I have not had an answer from you. I am fearfull the letters must have been lost, although all the others, I sent to England arrived, and have been acknowledg'd.

In my former letters I gave you some Idea of what I had been doing in this part of the World and my success in Collecting &c. I now will

give you a small Idea of my Voyages to the various provinces and Islands in this Government.

My first excursion was to the center part of Luzon, where I collected but a few things, from the state of Cultivation, &c.; the next, to the borders of the great lake where I collected about 200 species of plants, Ferns was the principal feature of the Trip. My next excursion to the Islands in the South as Panay, Guimaras, Negros, Siquijor, Zebu [Cebu], Bohol, Camiguing [Camiguin de Misamis] and Mindanao, which occupied 10 months and at the close the plants amounted to 1900 in all, in which were many Ferns. My last Trip has been a continuation of the Southern Islands, viz. Samar, Leyte, Masbate, Ticao, Burias, Mindoro and the South eastern Provinces of Luzon as Albay, Camarines, Tayabas and Batangas, here my Ferns have augmented vastly. I may say with propriety I have 400 species amongst which many Trees and one Shrub. In the Island of Samar I found a Rafflesia of which I have dried specimens and in spirits on the Roots of Trees, on which they grew, several species of Nepenthes, but few Flowers. Mosses, Lichens and Fucii are scarce, small annuals hardly any, shrubs but few, large Trees, and small ones, in abundance. The Vegetation is so luxurious the smaller plants cannot live, all open spaces are cover'd by high grass to 9 ft. high. My species now amount to 3000. The Ferns are magnificent of which I have ample sps. I have ascended several mountains to the very Top some 5, 6, and 7,000 Ft. high. On the Sea Coast nearly all the plants are the same in all localities; in the dark Woods and deep Glens is my delight. The Ill Health and fatigue that I have experienced has been very great, my Eyes are much injured by the sun; in short I am 10 years older than I ought to be. I am now preparing for the Northern part of the Island and expect to return in July next. In Oct. I leave this [place] for Singapore and that place in March 1840 for England of which I will advise you in time.

From the Govt. and all the Public authorities I am continually receiving proofs of their Friendship and protection and the Friars are my best Friends. My other Collections are equally rich, Shells, Birds, Insects &c. I have forwarded to the care of Mr. Brown a Trunk of a Tree Fern which I collected in the Crater of a Volcano; there were Thousands. I have but few small species some are so large that I have been compell'd to divide a leaf in four that has not a stem. In the North they are abundant in the Mountains. How I shall succeed I can't say as there is war betwixt the Negros and the White people and has been for some years. I must venture I cannot leave such a spot unsearch'd.

I have had the misfortune to have a large Case of plants stolen from the Warehouse in which it was deposited. I trust you will be able to procure for me several subscribers to take plants by the time I arrive in England, in the meantime

Believe me My dear Sir
Yours ever obliged most Sincerely
[Signed] H. CUMING.

Sir WILLIAM JACKSON HOOKER, KT.
L. L. D. F. R. S. &c.
Reg. Prof. Bot.
Glasgow.

216702——2

8, KING'S ROAD GRAYS INN
LONDON *June 5th 1840*

MY DEAR SIR,

It is with pleasure I have to inform you of my safe arrival here this morning from Singapore with all my Collections I trust safe, and in as good a Condition as I am in Health.

Since I did myself the pleasure of writing you last, I have been at Mount Ophir in the Malayan Peninsula and have had the great pleasure of Collecting the splendid Fern [*Matonia pectinata* R. Br.] which I promised you to do before I left and many others from that Locality. It is not found at the Foot of the Mountain but 4600 feet high in great abundance, of which I have taken the liberty of Collecting a number of the finest specimens. Its roots creep along the Ground and each Frond stands from 5 to 7 Feet high.

If I have my Health, I expect to have all the plants in Order by the latter end of August and if it should meet your convenience to be in London at that or at a future period I shall be most happy to see you when a division is made of the Specimens more particularly so as it is my wish for you to have the first Choice in all the plants as before.

I shall feel most gratefull to you in procuring me subscribers for Collections of plants amongst your Friends. Perhaps some of them may object from the amount of a Collection being paid down at once. To make it convenient to them it can be paid in four Instalments, the first at the time of receiving them, and at 3, 6 and 9 months if it meets their pleasure.

My address at present is at 8 Kings Road, Grays Inn, London, in the meantime I will exert myself to get all the plants in Order, those Families that I am acquainted with I will put together such as the Ferns, Orchideae, Malvaceae, with their Localities, time collected &c.

If you have leisure I shall be most happy to hear from you.

I have 15 Species of Ferns from St. Helena which I collected one day there. I met a Clergyman who informed me that he intended to send you some plants from that Island. I think his name was Phelps. As all my Baggage is on board I cannot find his card to be certain of his Name.

I am Dear Sir
Yours most Sincerely
[Signed] H. CUMING

80 GOWER STREET, BEDFORD SQUARE
Aug. 1, 1840.

MY DEAR SIR,

I hasten to inform you that I have found Seven of my Cases of plants completely ruin'd by Water, the Tin Cases being eaten through and full of Holes. It must have occur'd in Manila, where the Cases where placed in a Store over which lived a Family who must have let water fall through the Floor and as there was not any Ceiling it did not leave any marks behind.

It must have been in '38 or '39 as all the Cases injured were collected in '36 - '37 and one in the early part of '38 and a few boxes of Shells of those Years have been also wet. Shells will not damage but little.

I have unpack'd one of the damaged Cases and I am happy to say all the Species of Ferns are but little injured and you will not lose a Species in this Case. Most all the other plants are gone. Where a specimen could be recognized I have kept it for your inspection.

I am fearful the above loss will reduce my numbers to near 2,000 Species. If so my loss will be great but it is not any use to repine. I know that your disappointment will be great even more than mine.

I am My Dr. Sir
Yours ever oblidg'd
[Signed] H. CUMING

80 GOWER STREET
BEDFORD SQUARE
Oct. 13, 1840

MY DEAR SIR,

I have the pleasure to inform you that my labours in unpacking are nearly finished, as I have but one case to set in order which I expect to be done by the end of the Week.

Mr. Brown was heard from a few days since and may be expected in Town before the end of the month is up. Soon as he arrives I shall request him to consult you respecting the selecting of the plants that your convenience may be studied as it respects the time.

I trust you have had influence with some of the principal Botanists to become subscribers for a selection of my plants. As I have experienced your Friendship in so many instances it makes me a little bold to ask another Favour in the above.

I have not written to Baron Fischer of St. Petersburg under a supposition that you might have communicated with him on the subject, neither have I address'd the Revd. Mr. Henslow[14] of Cambridge, as you did me the favour to get him to subscribe the last time.

A Mr. Shuttleworth[15] of Switzerland made a communication to the late Mr. Hunneman for a Collection but as I do not know that Gentlemans address I have not written to him. If you can give me any information respecting that Gentleman you will oblidge me much.

If you think it necessary I will advise Mr. Fielding the plants are nearly ready. I dont know if he intends to be present or not or if he has appointed any person to look out his specimens.

I am of an opinion that some of the Gentlemen will be annoy'd by the size of many of the Ferns, many of them are Magnificent and I could not find courage to cut them to pieces where my papers would admit their size. I am certain there is more then 400 species. The Matonia is superb and I have specimens of all the different stages for you.

I remain Dear Sir
Yours ever oblidg'd
Most Sincerely
[Signed] H. CUMING

To
Sir W. J. HOOKER, KT.

[14] J. S. Henslow, 1796–1861.—E. D. M.
[15] R. G. Shuttleworth, 1810–1874.—E. D. M.

80 GOWER STREET
BEDFORD SQUARE
London 11th Sep 1840

My dear Sir,

I have just received a letter from Mr. Fielding of Bolton Lodge who writes me that he has been informed by you that my plants has been affected by Insects, which I am most happy to contradict in the fullest Sence—not having seen any symptoms of Insects or Dust in the 15 cases I have already unpacked. Six of the cases has been injured by Rain Water they having been placed in a large store in Manilla during my absence in the provinces and the Rain came upon them during one of the Bagios [typhoon] and not been noticed the water saturated the wood and corroded the Tins but am happy to say that not a fern is lost.

I beg the favour that if this report is in circulation that you will be pleased to contradict it in the fullest sence as it may tend to do me a serious injury which I trust I do not deserve.

I expect to have the Plants ready from the 20th to the 25th of next month—when ready and I do not hear from you in the meantime will write you again.

I remn Dear Sir
Yours truly

H. CUMING

Sir WILLIAM JACKSON HOOKER, KNT.

18 THAVIES INN
Saturday morning

MY DEAR SIR,

It is with great pleasure I forward to you my *Child*, with all its imperfections bad grammar &c. &c. &c. for your perusal and to select those portions that are fit to meet the public Eye. I tremble at the thought of appearing before the public in the light of a Tourist or of one attempting to describe a New Country. Do speak of it as a light trifling thing as notes taken down in the wearied hours of a man suffering under disease and Fatigue whose only recommendation is Industry and perseverance under a Thousand disadvantages.

My Friends the Spaniards be most kind, for their unbounded Hospitality, kindness and universal desire to further my object in every instance where it could be rendered, from the highest to the most Indigent.

If any dark passage meets your eye note it and let me put it aright for I have not had time to read over what I have written, and the universal bad language which I have written will give you a most mean opinion of your Humble Friend.

Don't forget the Ferns I should say at least 400 Species, I think more. Orchideae also is worthy of Notice; of plants 3500 species; Shells 3210 do. of which there are 576 species and varieties, Fluviatale, Univales 118, and but few Bivalves from the Lakes and rivers.

I shall feel most obliged for a Manuscript Copy previous to its being sent to the press that I may be able to correct the Names of places and other matters, and let a few Copies be printed of seperate, to give my own private friends who feel a Brotherly interest in the labours of their relative.

I have yet many little things to write from where I left of which I will do in due time as to let you have it by the time I receive your abstract of my Journal.

Relying on your great Influence with the Botanists of this, and other Countries, I repose the dreaded Book into your Hands, and trust I shall be able to raise sufficient subscribers to take the major part of my specimens to repay my very great expences in procuring them, to those who may not desire to take a Collection from the Expence do me the favour to inform them I shall be most happy to receive One Quarter part of the amount at the time of receiving them, and the remainder at 3, 6 and 9 months in Bills, which I promise not to negociate in any manner whatever untill due.

The above, I have stated from a Conviction of your Friendship for me and the universal esteem and respect which you are held by all the world which gives you that gigantic influence over all the Botanists of the Civilized Globe which leads me to hope will be a sure means of procuring a ready sale of my dried specimens.

I have the Honour to be
Yours most devoted
ever gratefull
[Signed] H. CUMING

N. B.

When you have occasion to write me from Glasgow address at 80 Gower Street Bedford Square.

80 GOWER STREET
BEDFORD SQUARE
May 25th 1841

MY DEAR SIR,

I had the pleasure to receive your Note last evening, in answer to which I beg to say the plants have been pack'd up since the 15th of April and knowing that you was in Scotland I did not think you would like to have them sent to Kew untill your return to Town.

I trust the selection that I have made will give you that satisfaction I would wish, whenever I had a doubt as to usefullness of the specimen for examination I always referr'd to Mr. Bennett,[16] who was present all the time with one to two exceptions.

Since the selection I found two or three things put aside and forgotten untill too late to put them into the cases. I will pack them securely and cause them to be left where you will be pleased to order them.

On the other side I have given the Number of specimens &c. &c.

Now my dear Sir I must beg your kind indulgence for appearant trifling on my part respecting my Journal. I am most truly sorry that I should have given you so much trouble and then disappointment in this affair. I now candidly confess that I felt so much asham'd of the gross Ignorance of the English Language which I made in writing of the Journal and which I have not the ability to amend that I was compell'd to write you what I did and as you was justly hurt at my appearant trifling I

[16] J. J. Bennet, 1801–1875.—E. D. M.

had not the courage to answer your just rebuke at the time when you had so much to attend to and of so much importance, I can assure you I have been much hurt ever since I received your letter particularly as I have from the first day that I had the Honour to be known to you received the greatest attention and acts of kindness from your Hands. If I could have the pleasure of seeing you at any time convenient to yourself I trust I should be able yet make some amend for the appearant trifling conduct of mine, that kind of conduct I most devoutly detest, and to labour under that Character in your estimation grieves me much.

I remain My dear Sir
Yours ever oblidg'd

H. CUMING

Sir W. J. HOOKER

80 GOWER STREET
BEDFORD SQUARE
Novr. 26, 1841

DEAR SIR,

I had the pleasure to receive yours of the 23d yesterday and as it was not in my power to answer it untill I had seen Mr. Bennett of the Museum who has kept a correct List of all the Localities. Today on my visiting the Museum I found he was taking his Holidays I will write him should he be at St. Johns Wood to gain what you desire.

At the time the plants where selected the Localities where put on the Number which began with a New Locality and I am confident they were put on yours as it was done to every set. I saw many of them when I pack'd them in the Box. I shall feel a pleasure in procuring you any information you want respecting them.

[Signed] H. CUMING.

The list of localities mentioned in the last letter is very important and although it has already been published by me [17] it is here repeated to complete this record. Cuming apparently intended to sort his plants into natural groups before numbering the collection as a whole, but abandoned this plan after he had segregated the ferns and fern allies, cellular cryptogams, and three strongly marked groups of phanerogams, *Eugenia,* Loranthaceæ, and the Orchidaceæ. In this task he was assisted by Mr. J. J. Bennett of the Botanical Department of the British Museum.

He used a printed label "Ins. Philippinae 1841" for the entire collection although several hundred numbers were not collected in the Archipelago, but came from the Malay Peninsula, Singapore, Sumatra, and St. Helena. The localities were not written on all the labels as the sets of duplicates were prepared, but the new locality was added on the label of the first number from that locality. It was apparently expected that subscribers to

[17] Philip. Journ. Sci. 10 (1915) Bot. 183.

the sets would complete the labels, but this was rarely or never done. The result has been that many of Cuming's extra-Philippine plants occur in various herbaria under Philippine labels and have erroneously been credited to the Archipelago in botanical literature, in some cases involving genera that do not extend to the Philippines.[18] Cuming's own list of localities attached to his letter of November 26, 1841, is given below.

1– 434. Vascular Cryptogams, apparently distributed with properly prepared labels. Most of the species are from the Philippines, a few from Malacca, Singapore, etc.
435– 667. Calauang [Calauan], Province of Laguna, Luzon.
678– 694. Province of Tayabas, Luzon.
695– 702. Island of Corregidor [a small island at the entrance of Manila Bay].
703– 725. Province of Tondo [Rizal], Luzon.
726– 749. Provinces of Pampanga and Bulacan, Luzon.
750– 833. Province of Tayabas and the mountains of St. Cristobal and Maijaijai [that is, Mount Banajao, on the boundary between Laguna and Tayabas Provinces], Luzon.
834– 947. Province of Albay, Luzon.
948–1039. Province of Pangasinan, Luzon.
1040–1112. Not localized, but probably from the Province of Zambales, Luzon, judging from the species represented.
1113–1182. Province of South Ilocos [Ilocos Sur], Luzon.
1183–1260. Province of North Ilocos [Ilocos Norte], Luzon.
1261–1380. Province of Cagayan, Luzon.
1381–1454. Province of Nueva Ecija, Luzon.
1455–1478. Province of South Camarines [Camarines Sur], Luzon.
1479–1603. Island of Mindoro.
1604–1673. Province of Misamis, Mindanao.
1674–1732. Island of Samar.
1733–1757. Island of Leyte.
1758–1789. Island of Cebu.
1790–1810. Island of Negros.
1811–1857. Island of Bohol.
1858–2153[18] Philippine material, not localized (exceptions 2052; 2053–2058).
2052. Malacca.
2053–2058. Singapore.
2252–2399. Malacca.
2400–2427. Singapore.
2428–2443. Sumatra.
2444–2464. St. Helena.

It is manifest that Cuming did not collect botanical material on all the islands he visited, for the published record shows

[18] See Vidal, Rev. Pl. Vasc. Filip. (1885) 83: "2154–2242 Criptogamas celulares." These were chiefly from the Philippines.

that he secured shells from Capul, Tablas, Temple, Guimaras, Burias, Camiguin de Misamis, Lubang, Siquijor, Bantayan, and Cuyo, islands that are not mentioned by him as localities in which he collected botanical material. Many of these islands are rather small, and most, but not all of them, are uninteresting from a botanical standpoint.

PARTIAL BIBLIOGRAPHY

This partial bibliography includes only papers based wholly or in large part on Philippine material collected by Hugh Cuming. Very many of them were originally printed in the Proceedings of the Zoölogical Society, London, here abbreviated as P. Z. S., and those there published were for the most part reprinted without change in form or title in the Annals and Magazine of Natural History, here abbreviated as A. M. N. H. These reprinted papers in the Annals and Magazine of Natural History sometimes appeared during the same year in which they were originally published in the Proceedings of the Zoölogical Society, sometimes the year following, and in some cases two years after they were originally printed. The original place of publication of all species considered in these two serials is in the Proceedings of the Zoölogical Society.

ADAMS, A.

On the animal of Liotia; with a description of new species of Delphinula and Liotia, from the Cumingian collection. P. Z. S. 18 (1850) 50–52, *t. 8;* A. M. N. H. II 7 (1851) 332–335.

Monograph of Sphaenia, a genus of lamellibranchiate Mollusca. P. Z. S. 18 (1850) 86–89; A. M. N. H. II 7 (1851) 420–421.

A monograph of Scarabus, a genus of air-breathing gasteropodous Mollusca from specimens in the Cumingian collection. P. Z. S. 18 (1850) 147–152; A. M. N. H. II 8 (1851) 66–70.

A catalogue of the species of Emarginula, a genus of gasteropodous Mollusca, belonging to the family Fissurellidae, in the collection of H. Cuming, Esq. P. Z. S. 19 (1851) 82–92; A. M. N. H. II 11 (1853) 146–153.

Catalogue of the species of Nassa, a genus of gasteropodous Mollusca belonging to the family Buccinidae, in the collection of Hugh Cuming, Esq., with the descriptions of some new species. P. Z. S. 19 (1851) 94–114; A. M. N. H. II 11 (1853) 320–325, 410–418.

Descriptions of fifty-two new species of the genus Mitra, from the Cumingian collection. P. Z. S. 19 (1851) 132–141; A. M. N. H. II 12 (1853) 48–58.

Contributions towards a monograph of the Trochidae, a family of gasteropodous Mollusca. P. Z. S. 19 (1851) 150–192; A. M. N. H. II 12 (1853) 142–148, 199–213.

A monograph of the genus Monoptygma of Lea. P. Z. S. 19 (1851) 222–224; A. M. N. H. II 12 (1853) 281–283.

ADAMS, A.—Continued.

A monograph of the recent species of Rimula, a genus of Mollusca, belonging to the family Fissurellidae. P. Z. S. 19 (1851) 226–227; A. M. N. H. II 12 (1853) 284–285.

Descriptions of sixteen new species of Rissoina, a genus of marine gasteropodous mollusks, from the Cumingian collection. P. Z. S. 19 (1851) 264–267; A. M. N. H. II 13 (1854) 65–68.

Descriptions of several new species of Murex, Rissoina, Planaxis, and Eulima, from the Cumingian collection. P. Z. S. 19 (1851) 267–272; A. M. N. H. II 13 (1854) 152–156.

Descriptions of new species of Eulima, Triphorus, etc., from the collection of Hugh Cuming, Esq. P. Z. S. 19 (1851) 276–277.

BENTHAM, G.

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BRODERIP, W. J.

Descriptions of species of Bulinus collected by H. Cuming, Esq. P. Z. S. 9 (1841) 14–16; A. M. N. H. 8 (1842) 380–382.

Descriptions of shells collected by H. Cuming, Esq., in the Philippine Islands. P. Z. S. 8 (1840) 83–87, 94–96, 119–125, 155–159, 180–182; 9 (1841) 22–23, 34–39, 44–46; 10 (1842) 53–55; A. M. N. H. 7 (1841) 226–229, 335–337, 546–551; 8 (1842) 62–66, 148–150, 380–382, 466–467, 527–531.

CARPENTER, P. P.

Description of new species and varieties of Calyptreidae, Trochidae, and Pyramidellidae, principally in the collection of Hugh Cuming, Esq. P. Z. S. 26 (1856) 166–171.

DESHAYES, G. P.

Descriptions of new species of shells in the collection of Mr. Cuming. P. Z. S. 21 (1853) 1–11; 22 (1854) 13–23, 62–72, 317–371.

Sur le genre Galeomma, Turton. P. Z. S. 23 (1855) 167–171.

Sur le genre Scintilla. P. Z. S. 23 (1855) 171–181.

Descriptions de nouvelles espéces du genre Erycina. P. Z. S. 23 (1855) 181–183.

DILLWYN, L.

On an undescribed species of Megapodius. P. Z. S. 19 (1851) 118–119, *t. 39;* A. M. N. H. II 11 (1853) 469–471.

DUNKER, G.

Myrtilacea nova collectionis Cumingianae. P. Z. S. 26 (1856) 358–366.

FRASER, L.

Description of two new species of birds from Luzon. P. Z. S. 7 (1839) 112–113; A. M. N. H. 5 (1840) 60–61.

GASKOIN, J. S.

On new species of Cypraea. P. Z. S. 11 (1843) 23–25; A. M. N. H. 13 (1844) 71–73.

Description of new species of the genus Cypraea. P. Z. S. 16 (1848) 90–98.

HANLEY, S.

Descriptions of new species of Mytilacea, Amphidesma, and Odostomia. P. Z. S. 12 (1844) 14–18; A. M. N. H. 14 (1844) 367–370.

Descriptions of new species of Tellina, collected by H. Cuming, Esq. P. Z. S. 12 (1844) 59–64, 68–72, 140–144, 146–149, 164–166; A. M. N. H. 14 (1844) 504–509; 15 (1845) 46–50, 363–371, 435–437.

Descriptions of new species of Cytherea. P. Z. S. 12 (1844) 109–110.

Descriptions of new species of Cyrena, Venus, and Amphidesma. P. Z. S. 12 (1844) 159–162; A. M. N. H. 15 (1845) 431–435.

Descriptions of new species of Ostrea, in the collection of Hugh Cuming, Esq. P. Z. S. 13 (1845) 105–107; A. M. N. H. 17 (1846) 288–290.

HASSKARL, J. K.

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HINDS, H. B.

On two new species of Triphoris, in the collection of H. Cuming, Esq. P. Z. S. 11 (1843) 22–23; A. M. N. H. 12 (1843) 449.

Descriptions of shells collected during the voyage of H. M. S. Sulphur, and by H. Cuming, Esq. P. Z. S. 12 (1844) 72–77, 96–98; A. M. N. H. 14 (1844) 436–446.

JONAS, J. H.

Descriptions of new species of shells belonging to the genera Helix and Bulinus, collected by Mr. Cuming in the Philippine Islands. P. Z. S. 10 (1842) 188–189; A. M. N. H. 12 (1843) 365–366.

LEA, J.

Description of five new species of Anodontae collected by H. Cuming, Esq., in the East Indies. P. Z. S. 18 (1850) 197–199; A. M. N. H. II 8 (1851) 493–496.

LEA, J., and H. C.

Description of a new genus of the family Melaniana, and of many new species of the genus Melania, chiefly collected by Hugh Cuming, Esq., during his zoölogical voyage in the East, and now first described. P. Z. S. 18 (1850) 179–197; A. M. N. H. II 9 (1852) 58–70, 142–148.

MARTIN, W.

On two specimens of saurian reptiles sent to the society by Mr. Cuming. P. Z. S. 6 (1838) 68–70; A. M. N. H. 3 (1839) 68–70.

MERRILL, E. D.

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PFEIFFER, L.

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Descriptions of new species of shells, collected by H. Cuming, Esq., in the Philippine Islands. P. Z. S. 10 (1842) 150–153; A. M. N. H. 12 (1843) 138–141.

Descriptions of new species of Helix and a new Glandina, in the collection of Hugh Cuming, Esq. P. Z. S. 13 (1845) 38–42; A. M. N. H. 16 (1845) 253–257.

Descriptions of new species of land-shells from the collection of Hugh Cuming, Esq. P. Z. S. 13 (1845) 43–61; A. M. N. H. 16 (1845) 332–335.

Descriptions of twenty-two new species of land-shells in the collection of Hugh Cuming, Esq. P. Z. S. 13 (1845) 63–68; A. M. N. H. 16 (1845) 336–341.

Description of a new species of Amphipeplea. P. Z. S. 13 (1845) 68; A. M. N. H. 16 (1845) 341.

Descriptions of twenty-two new species of Helix. P. Z. S. 13 (1845) 71–75; A. M. N. H. 16 (1845) 341–346.

Descriptions of fourteen new species of Helix from the collection of Hugh Cuming, Esq. P. Z. S. 13 (1845) 123–125; A. M. N. H. 17 (1846) 431–434.

Descriptions of thirty-six new species of Helix from the collection of Hugh Cuming, Esq. P. Z. S. 13 (1845) 126–133; A. M. N. H. 17 (1846) 434–441.

Descriptions of thirty new species of Helicea, belonging to the collection of Hugh Cuming, Esq. P. Z. S. 14 (1846) 28–34; A. M. N. H. 18 (1846) 58–64.

Descriptions of twenty new species of Helicea, in the collection of Hugh Cuming, Esq. P. Z. S. 14 (1846) 37–41; A. M. N. H. 18 (1846) 123–127.

Descriptions of nine new species of Helicea, collected by Hugh Cuming. P. Z. S. 14 (1846) 41–43; A. M. N. H. 18 (1846) 127–129.

Descriptions of twenty-three new species of Vitrina from the collection of H. Cuming, Esq. P. Z. S. 16 (1848) 104–109.

Descriptions of fourteen new species of Helicina from the collection of H. Cuming, Esq. P. Z. S. 16 (1848) 109–112.

Descriptions of twenty-three new species of land shells, from the collection of H. Cuming, Esq. P. Z. S. 21 (1853) 48–54.

PHILIPPI, R. A.

Descriptions of new species of Trochus, and of eighteen new species of Littorina, in the collection of Hugh Cuming, Esq. P. Z. S. 13 (1843) 138–143; A. M. N. H. 17 (1846) 443–447.

RECLUZ, C. A.

Descriptions of various species of Navicella, collected by Hugh Cuming, Esq., in the Philippine Islands. P. Z. S. 10 (1842) 154–160; A. M. N. H. 12 (1843) 141–147.

RECLUZ, C. A.—Continued.

Descriptions of new species of Nerites, collected by H. Cuming, Esq., in the Philippine Islands. P. Z. S. 10 (1842) 168–176; A. M. N. H. 12 (1843) 276–284.

On new species of Narica. P. Z. S. 11 (1843) 136–141; A. M. N. H. 14 (1844) 57–59.

Descriptions of new species of Navicella, Neritina, Nerita, and Natica, in the collection of Hugh Cuming, Esq. P. Z. S. 11 (1843) 197–214; A. M. N. H. 14 (1844) 130–145.

Déscription de quelques nouvelles Nérites fluviatiles du cabinet de H. Cuming, Esq. P. Z. S. 13 (1845) 119–122; A. M. N. H. 17 (1846) 292–293.

Description d'une nouvelle espéce de Conovulus. P. Z. S. 13 (1845) 122; A. M. N. H. 17 (1845) 295.

REEVE, L.

Description of a new species of Corbis, a genus of acephalous molluscs of the family Nymphacea. P. Z. S. 9 (1841) 85–96; A. M. N. H. 9 (1840) 501.

Characters of a new species of Nitra, a genus of pectinibranchiate molluscs of the family Columellata. P. Z. S. 9 (1841) 93; A. M. N. H. 10 (1842) 509.

Descriptions of new species of shells, principally from the collection of Hugh Cuming, Esq. P. Z. S. 10 (1842) 49–50; A. M. N. H. 11 (1843) 308–309.

Descriptions of new species of Delphinula, a genus of pectinibranchiate molluscs of the family Turbinacea. P. Z. S. 10 (1842) 102–104; A. M. N. H. 11 (1843) 521–523.

Descriptions of new species of shells belonging to the genera Trochus and Turbo. P. Z. S. 10 (1842) 184–186; A. M. N. H. 12 (1843) 286–288.

Descriptions of four new species of Conus. P. Z. S. 11 (1843) 12–13; A. M. N. H. 12 (1843) 449.

A new species of Delphinula. P. Z. S. 11 (1843) 141–143; A. M. N. H. 13 (1844) 515–517.

On new species of Conus, Pleurotoma, Pectunculus, Cardita, and Cypricardia. P. Z. S. 11 (1843) 168–196; A. M. N. H. 14 (1844) 297–309.

Descriptions of seven new species of Glauconome. P. Z. S. 12 (1844) 19–21; A. M. N. H. 14 (1844) 372–373.

Descriptions of thirty-three new species of Arca. P. Z. S. 12 (1844) 39–48; A. M. N. H. 14 (1844) 486–495.

Monograph of the genus Myadora. P. Z. S. 12 (1844) 91–94; A. M. N. H. 15 (1845) 61–64.

Descriptions of new species of Triton, collected chiefly by Hugh Cuming, Esq. P. Z. S. 12 (1844) 110–122; A. M. N. H. 15 (1845) 199–210.

Descriptions of new species of Arca, from the cabinet of Hugh Cuming, Esq. P. Z. S. 12 (1844) 123–128; A. M. N. H. 15 (1845) 355–359.

Descriptions of new species of Ranella. P. Z. S. 12 (1844) 136–140; A. M. N. H. 15 (1845) 360–363.

REEVE, L.—Continued.

Descriptions of new species of Nitra and Cardium. P. Z. S. 12 (1844) 167–187; A. M. N. H. 15 (1845) 475–495.

Descriptions of eighty-nine new species of Mitra, chiefly from the collections of Hugh Cuming, Esq. P. Z. S. 13 1843) 45–61; A. M. N. H. 16 (1845) 257–273.

Descriptions of new species of Murex. P. Z. S. 13 (1845) 85–88; A. M. N. H. 17 (1846) 129–132.

On new species of Pleurotoma. P. Z. S. 14 (1846) 3–6; A. M. N. H. 17 (1846) 478–481.

Descriptions of fifty-four new species of Mangelia from the collections of Hugh Cuming, Esq. P. Z. S. 14 (1846) 59–65; A. M. N. H. 18 (1846) 202–208.

Descriptions of new species of Chama. P. Z. S. 14 (1846) 117–120; A. M. N. H. 19 (1847) 270–273.

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The localities of Cuming's Philippine plants. Kew Bull. (1908) 116–119.

SAUSSAYE, P. DE LA.

Descriptions of new species of shells belonging to the genus Auricula, collected by H. Cuming, Esq. P. Z. S. 10 (1842) 201–202; A. M. N. H. 12 (1843) 437–438.

Descriptions of Elasmatina and Scarabus in the collection of H. Cuming, Esq. P. Z. S. 11 (1843) 2–3; A. M. N. H. 12 (1843) 439–440.

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SOWERBY, G. B.

Descriptions of shells collected by H. Cuming, Esq., in the Philippine Islands. P. Z. S. 8 (1840) 87–91, 96–104, 116–118, 135–137, 167–169; A. M. N. H. 7 (1841) 230–234, 337–344, 543–545, 560–561; 8 (1842) 72–74.

On some new species of the genus Cardium chiefly from the collection of H. Cuming, Esq. P. Z. S. 8 (1840) 105–111; A. M. N. H. 7 (1841) 506–511.

Descriptions of some new species of Murex, principally from the collection of H. Cuming, Esq. P. Z. S. 8 (1840) 137–147; A. M. N. H. 7 (1841) 562–571.

Descriptions of new species of shells collected by H. Cuming, Esq., in the Philippine Islands. P. Z. S. 9 (1841) 1–3, 17–20, 24–26, 39–40; A. M. N. H. 8 (1842) 383–387, 467–470, 531–533.

Descriptions of eight new species of the genus Ranella. P. Z. S. 9 (1841) 51–53; A. M. N. H. 8 (1842) 538–540.

Descriptions of several new species of Chitones brought by H. Cuming, Esq., from the Philippine Islands. P. Z. S. 9 (1841) 61–62; A. M. N. H. 9 (1842) 60–61.

Descriptions of nine species of the genus Pupina. P. Z. S. 9 (1841) 101–103; A. M. N. H. 10 (1842) 213–217.

SOWERBY, G. B.—Continued.

Descriptions of four species of the genus Chiton, brought by H. Cuming, Esq., from the Philippine Islands. P. Z. S. 9 (1841) 104; A. M. N. H. 10 (1842) 216–217.

Descriptions of some new species of Helicinae, in the collection of H. Cuming, Esq. P. Z. S. 10 (1842) 6–8; A. M. N. H. 10 (1842) 400–402.

Descriptions of new species of shells belonging to the genus Cyclostoma, collected by H. Cuming, Esq., in the Philippine Islands. P. Z. S. 10 (1842) 80–94; A. M. N. H. 11 (1843) 466–471.

Descriptions of two new species of shells belonging to the genus Strombus, collected by H. Cuming, Esq. P. Z. S. 10 (1842) 193–194; A. M. N. H. 12 (1843) 132–133.

Descriptions of new species of Lima. P. Z. S. 11 (1843) 23; A. M. N. H. 13 (1844) 71.

On new species of Cyclostoma in the collection of H. Cuming, Esq. P. Z. S. 11 (1843) 29–31; A. M. N. H. 13 (1844) 130–132.

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Descriptions of new species of Columbella, from the collection of Hugh Cuming, Esq. P. Z. S. 12 (1844) 48–53; A. M. N. H. 14 (1844) 495–501.

Descriptions of some new species of Ovulum in the collection of Mr. Cuming. P. Z. S. 16 (1848) 135–136.

Descriptions of some new species of Cancellaria in the collection of Mr. H. Cuming. P. Z. S. 16 (1848) 136–138.

On a new genus of Pholadidae, with notices of several new species and of a remarkable specimen of Pholas calva in Mr. Cuming's collection. P. Z. S. 17 (1849) 160–162, *t. 5.*; A. M. N. H. II 6 (1850) 299–302.

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Description of a new species of squirrel (Sciurus philippinensis) from the Philippine Islands. P. Z. S. 7 (1839) 117–118; A. M. N. H. 5 (1840) 63–64.

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Descriptions of various coleopterous insects brought from the Philippine Islands by Mr. Cuming. A. M. N. H. 8 (1841) 221–222.

Descriptions of new species of coleopterous insects belonging to the genus Apocyrtus, collected by Hugh Cuming, Esq., in the Philippine Islands. A. M. N. H. 9 (1842) 302–311; 11 (1843) 247–255.

Descriptions of some new longicorn and rhynchophorous beetles from the Philippine Islands. A. M. N. H. 10 (1842) 70.

Descriptions of two new species of the genus Mus. P. Z. S. 10 (1842) 145–146; A. M. N. H. 12 (1843) 131–135.

On various species of bats collected by H. Cuming, Esq., in the Philippine Islands. P. Z. S. 11 (1843) 66–68; A. M. N. H. 13 (1844) 302–304.

On a new species of Megaderma. P. Z. S. 11 (1843) 69; A. M. N. H. 13 (1844) 304.

On new species of bats collected in the Philippine Islands and presented to the society by Hugh Cuming, Esq. P. Z. S. 13 (1845) 3–10; A. M. N. H. 16 (1845) 49–56.

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Short descriptions of new or little known decapod Crustacea. P. Z. S. 14 (1846) 222–228.

ILLUSTRATION

PLATE 1. Hugh Cuming, 1791–1865.

PLATE 1. HUGH CUMING, 1791–1865.

ORIGIN, DEVELOPMENT, AND NATURE OF THE STONY LAYER OF THE COCONUT (COCOS NUCIFERA LINNÆUS) [1]

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THREE PLATES

INTRODUCTION

Most of the researches on the coconut have been purely physiological, chemical, or agronomical; morphologically, very little has been done. This paper has for its main purpose the report of a critical study of the origin, development, and nature of the stony layer, or shell, of the coconut (*Cocos nucifera* Linnæus) and the surrounding tissues. The report includes an account of the development of the spadix, the female flower, and the fruit. The reader is referred to the work of Quisumbing(10) for a description of the development of the stony layer in the most important groups of gymnosperms and in a few of the angiosperms.

The literature dealing with the inflorescence and the female flower consists mostly of taxonomic descriptions; apparently the ontogeny has not been studied.

Taxonomists in general regard the fruit of the coco as a drupe consisting of a smooth, tough, brownish to grayish epicarp; a fibrous, mottled brown mesocarp; and a hard, thick, brown endocarp within which is the endosperm inclosed in a closely adhering testa. Very few botanists have attempted to describe the parts of the fruit anatomically. Winton(13) is the only investigator who has given a detailed histological description of the tissues of the mature nut. Wiesner(12) made microscopical examinations of the individual cells constituting the shell and found that the ground tissue was sclerenchymatous, with

[1] Thesis presented for graduation for the degree of Master of Science in Botany, University of the Philippines, No. 222, Experiment Station contribution No. 356.

[2] Read before the Los Baños Biological Club, December 11, 1924.

cells of different shapes. He conducted microchemical tests of the outer and inner *Samenhaut* and found that the cell walls of the outer turned red with phloroglucin-hydrochloric acid and the inner exhibited a negative reaction. Winton,(13) describing the individual cells, states that they possess thick, deep yellow walls with branching pores and dark brown contents. They are either isodiametric or strongly elongated, being usually spindle- or wedge-shaped; but hooked and various other curious forms also occur.

MATERIAL AND METHODS

The material used in this study was gathered on July 16, 1923, from six apparently healthy and vigorously growing trees in the Bacomo Coconut Plantation of the College of Agriculture, University of the Philippines. The method of attack was from the large mature nuts to the last spadix of the trees. As a result two of the trees were killed and all visible spadices were fixed. Slabs were sliced from the four sides of the younger pistils with their floral envelopes, and the remainder fixed in toto. Ovaries of intermediate age and older were cut into blocks of about 1 cubic centimeter, selected from the chalazal, middle, and micropylar regions, and then fixed.

Several fixing agents were tried, but formo-alcohol (Chicago formula) (3) and formo-aceto-alcohol were most satisfactory. A 1 per cent chromo-acetic fixative was found to preserve the material well, but made cutting difficult. Hot corrosive sublimate reagent was also tried; fixation was rapid, but this reagent caused the material to shrink and the cell walls to collapse.

After fixing, the material was washed as usual, dehydrated by passing through successive grades of alcohol, de-alcoholized in several ascending series of xylols, embedded in paraffin, and cut with a Spencer rotary microtome into sections of 7 to 10 microns in thickness. In the case of the mature stony layer, the material was first cut into small pieces of 0.5 by 3 centimeters, and then boiled for some time in water. The pieces were allowed to cool and were then transferred to hydrofluoric acid of full strength. After forty-two days they were washed in running water and cut with the aid of the Bausch and Lomb sliding microtome. Softer ones were cut without immersing them in hydrofluoric acid.

Several stains were tried. Flemming's triple stain and Haidenhain's iron-alum hæmatoxylin with orange gold, dissolved in clove oil as background, proved to be satisfactory.

THE INFLORESCENCE

The inflorescence of the coco palm, surrounded and inclosed by large, tough sheathing bracts called spathes, arises at the axil of the petiole. The whole flower cluster (Plate 1, fig. 1) consists of a central axis, the rachis, from which the rachillæ (Plate 1, fig. 2) arise in spiral succession. At their apices the rachillæ bear male flowers in the axils of the tertiary bracts, singly or in pairs, and female flowers at their bases. Teratological cases have been reported by Andy,(1) Burkill,(2) Furtado,(5) Parthasarathy Iyengar,(8) Petch,(9) and Smith,(11) in which "bulbiliferous coconut with deciduous and sterile inflorescence develops leaves instead of flowers."

The inflorescence initial begins as a minute protuberance at the axil of the clasping petiole (Plate 1, fig. 3). Arising at the basal portion of the inflorescence initial are two primary clasping bracts (Plate 1, figs. 3 and 4), one of which is situated toward the "cabbage," and the other between the petiole and the inflorescence initial. The first primary bract (Plate 1, fig. 5) envelops the second primary bract. Both of these bracts outgrow the whole floral cluster, thus forming two envelopes, the outer and the inner spathes, surrounding the actively growing inflorescence. The apex of this meristematic tissue of the inflorescence initial when 240 microns in length and 270 microns in width (Plate 1, figs. 3 and 4) shows signs of the formation of the primary inner bract which later develops into a persistent inflorescence envelope. After the spathes have formed complete envelopes to the growing point of the inflorescence, the cone gives rise to lateral protuberances which later develop into the secondary bracts (Plate 1, fig. 5). The lower secondary bracts tend to elongate more rapidly than do those at the apex so that their tips (Plate 1, figs. 6 and 7) are nearly as long as the apex of the main axis of the whole inflorescence. Concomitant with the production of secondary bracts by the main axis, and following them in succession, primordia of the rachillæ (Plate 1, fig. 8) make their appearance at the axils of the basal secondary bracts. They elongate vertically and parallel to the main axis of the inflorescence (Plate 1, fig. 9), leaving the secondary bracts behind. These axillary lateral primordia of the main axis of the inflorescence develop as secondary axes, rachillæ, which occur in spiral succession throughout the whole length of the main axis. The rachis almost always terminates with a single rachilla similar to its lateral branches. The rachillæ in turn give rise to lateral outgrowths, or tertiary bracts, which serve

as temporary floral envelopes (Plate 1, figs. 10 and 11). At the axils of the tertiary bracts, the flowers develop. All the bracts, primary, secondary, and tertiary, are persistent, even in the mature, dried specimens. The secondary and tertiary bracts never attain great size.

THE FEMALE FLOWER

The female flowers arise at the axils of the tertiary bracts, which are tiny, collarlike structures at the very basal portion of the flowers and are hardly distinguishable after the maturity of the pistils. The female flowers can be distinguished from the male flowers by their size and shape; both male and female flowers are developed on the same rachilla. In some varieties of coco palm, especially those with pink pistils when young, the female flowers can be easily distinguished from the male flowers in the cluster by their color and size. The female flowers are pinkish and the male flowers outnumber them; the former are somewhat spherical, whereas the latter are triangular (Plate 1, fig. 1). The younger and smaller the inflorescence the less marked the difference between the female and the male flowers. On nearly every rachilla one, two, three (Plate 2, fig. 1), or five (in rare cases as many as nine) female flowers develop. The peripheral rachillæ nearly always bear male flowers. Subtending each female flower are eight floral envelopes, as reported by Furtado(4) and Möbius.(7) However, taxonomists consider the female flower to possess only six floral envelopes, three sepals, and three petals. The first two and outer floral envelopes are small and have a scaly appearance, from which the name *Schuppenblätter* was derived. These were called bracteoles, or prophylls, by Furtado;(4) they are rendered inconspicuous by the developing fruit, later losing their identity as floral envelopes. Within these two scaly leaves (bracteoles) are three sepals which envelop the whole pistil. The outermost and largest of the three sepals nearly covers the whole flower, its apex reaching the tip of the pistil. They are characterized by their prolific production of cells containing raphides. The petals, three in number, are located within these sepals and are much thinner and paler. Subtending the ovary at its base is a thin yellowish ring, the aril. Within the appressed covering of floral envelopes is the more or less spherical pistil with sessile stigmas. Before and just after the opening of the inner spathe, the pistil is inclosed by the floral envelopes and it emerges only after two or three weeks. The ovary is tricarpous (Plate 2, fig. 3), and each carpel possesses an ovule (Plate 2, figs. 3 and 4). One ovule

usually functions, and the other two either abort or degenerate. Cases of two or three functional ovules are rare.

The individual female flower starts its ontogenetic development as an emergence in the axil of the tertiary bract of the rachilla. Two or three floral primordia may arise simultaneously from the axil of a tertiary bract. If only a female flower is developed, the male flowers around it may degenerate (Plate 2, fig. 1). Nearly all the cells of the undifferentiated outgrowths are isodiametric. The mode of development of the floral organs is centripetal (Plate 2, figs. 5 to 8). At the axil of the tertiary bract and the floral cone, two scale leaves appear as two small papillate protrusions which elongate, bend, and cover the juvenile flower (Plate 2, fig. 5). As soon as these bracteoles have developed, the three sepals develop simultaneously from the basal portion of the flower primordium, one overlapping the others toward the apex (Plate 2, fig. 6). The sepals also elongate, pushing their way between the bracteoles and the floral cone. The petals which alternate with the sepals next emerge simultaneously (Plate 2, figs. 6 and 7), first as rudimentary papillæ, but soon differentiate into scalelike structures like the sepals (Plate 2, fig. 6). They do not develop as much as do the sepals. Next to the last structure of the female flower to develop is the aril (Plate 2, fig. 8). The carpels develop and mature last (Plate 2, figs. 7 and 8).

On removal of the floral envelopes, there is seen around the apex of the pistil and near the stigmas some powdery white material which, upon scraping and mounting in water on a slide, is found to be composed of multicellular scales consisting of numerous thin-walled papillate cells, the free ends of which are rounded. Inclosed among them are large, round, more or less spheroid cells containing raphides. Möbius(6) observed them only on the young female and unopened flower. In my specimens these powdery white scales with specialized cells containing raphides were found, not only on the juvenile female flowers, but also on the juvenile rachis and rachillæ. They can be found also all over the spathes. These white powdery scales around the stigmas persist on the young fruit and disappear only when the fruit matures.

When the inflorescence emerges from the inner spathe, the ovules have already developed within the thick carpel wall. Each ovule possesses two coats (Plate 2, figs. 4 and 9; Plate 3, fig. 15). Extending from the stigmas is the conducting tissue composed of palisaded cells. This tissue trifurcates as it passes

down to the loculi, or cells, of the ovary. An anatropous ovule completely fills each of the loculi. Winton's(13) results agree with mine in showing that the ovary has three ovules, all of which are anatropous.

ORIGIN AND DEVELOPMENT OF THE STONY LAYER OF THE FRUIT

The fruit.—After fertilization, the growth of the fruit follows, the pericarp developing most rapidly at the basal region which remains soft and whitish until the fruit is nearly mature. Long before the time of fertilization (that is, before the pistils emerge from the floral envelopes) the endocarp is already differentiated as a soft, creamy white structure surrounding the loculi.

As the fruit develops and matures, the embryo sac increases in size, leaving a large vacuole at the center. The embryo sac is at first rounded, then it elongates and widens until near maturity. The fruit of the particular variety here reported upon loses its conical shape (Plate 2, figs. 2, 10, and 11) in the early part of the elongating period and becomes spheroidal to orbicular (Plate 2, figs. 12 to 16; Plate 3, figs. 1 to 5) as it matures.

When the fruit is young the mesocarp composes the major portion of the pericarp, being wider near the stigmas and sides and very narrow at the portion which attaches the fruit to the rachilla. During its development, the mesocarp up to maturity increases in thickness in the region opposite the stigmas, or near the micropylar end of the ovules. The exocarp always remains tough and hard, losing its green color when old, the final color varying with the variety. The number of fibrovascular bundles in the mesocarp increases with development, so that at maturity the fruit contains numerous fibers.

The stony layer.—Before the ovules are formed, the pericarp wall is homogenous in structure and is composed of isodiametric cells. As the loculi of the ovary develop, and just before the ovules are formed, the pericarp wall undergoes triple differentiation (Plate 2, fig. 8; Plate 3, fig. 6). The outermost layer of cells becomes squarish to elongated horizontally. The hypodermal cells are isodiametric. The cells within the hypodermis are large, and the innermost part of the pericarp wall is composed of small rectangular to squarish cells. The pericarp, then, has undergone differentiation long before the ovules are formed into (*a*) an outer single layer of squarish to elongated cells, the exocarp; (*b*) the large isodiametric cells of the mesocarp; and (*c*) the small isodiametric cells of the endocarp.

By the time of the appearance of the ovules, the mesocarp cells have already undergone advanced and complete differentiation. At the juncture of the stigmas and the ovary, the cells of the mesocarp which have rounded corners elongate horizontally and enlarge. Cell enlargement continues downward toward the basal portion of the ovary. Simultaneously with differentiation of the mesocarp is the appearance of the tanniferous cells, starting from the stigmas and continuing downward. Further differentiation of the mesocarp is marked by the production of more tanniferous idioblasts soon after the opening of the inner spathe (Plate 3, fig. 7). While the differentiation of the mesocarp is in progress, the endocarp cells remain isodiametric.

The exocarp cells, which remain always one layer in thickness, elongate tangentially and develop a thick outer wall (Plate 3, fig. 6) as they mature.

While the mesocarp undergoes differentiation, the endocarp remains as a clear, white structure in the innermost portion of the pericarp and starts its further differentiation soon after the mesocarp is differentiated. The cells have no tannin (Plate 3, fig. 7). The walls toward the loculi are lined by palisaded cells from the stigmatic point downward. Just adjacent to this single layer of palisaded cells, one to three rows of horizontally elongated, more or less compressed cells are evident. These are bordered within toward the mesocarp by isodiametric cells which become larger as they approach the loculi. Juvenile fibrovascular bundles are present (Plate 3, fig. 7). The peripheral cells of the endocarp at the micropylar end become vertically palisaded, becoming isodiametric at the hypodermis and within.

Further increase in size of the endocarp is due to further cell division and cell enlargement. The presence of elongated and isodiametric cells in either transverse or longitudinal sections of the endocarp is very conspicuous, especially in mature specimens, and this variable development is due to anticlinal and periclinal divisions of the cells. As the endocarp develops, the palisaded condition of the cells at the sides toward the loculi disappears and it persists only at the apical and basal regions. Some of these palisaded cells in the micropylar region divide, producing two or three layers of cells, and the cells assume either an oblique, a horizontal, or a vertical position (Plate 3, fig. 9).

The process of cell lignification (Plate 3, figs. 1 to 6) is similar to that found in *Sassafras sassafras*,(10) where lignification starts at the apical region and ends at the basal region. As lig-

nification proceeds to the basal region, it is seen first in the middle of the endocarp layer and progresses simultaneously inward and outward to the mesocarp. The lignified cells of the endocarp are at first colorless, but later turn yellowish brown and finally dark chocolate brown. The change in color, like the lignification, proceeds from the stigmatic point to the basal end of the fruit and from the middle toward the sides of the layer of the endocarp. The dark chocolate or chocolate brown color of the endocarp is its characteristic feature, in which it differs macroscopically from the mesocarp and also from the integumental layers.

Winton(13) found that the mature stone cells show variability in form; some are rounded, others oblong, and still others elongated (Plate 3, fig. 10). They are dark yellow under the microscope, but the whole layer is dark chocolate as seen by the naked eye. The walls are striated and traversed by simple and branching pores. The lumina are very small and contain a dark brown substance. The cells near the mesocarp have thinner walls and larger lumina than those near the ovary cavity.

The "eyes" show certain interesting morphological peculiarities. In a nut three eyes are present but, evidently, if only one embryo is developed, one eye becomes functional, and the other two are nonfunctional. Upon examination of a mature nut, the fertile eye appears to be a depression (Plate 3, fig. 5). The depression here is due to the failure of the endocarp (excepting a single layer of cells) to lignify. The remainder of the covering of this eye is composed of spongy parenchymatous tissue which morphologically belongs to the endocarp. The fertile eye, therefore, becomes covered only by a very thin plate of lignified cells formed from the palisaded layer of the endocarp and from the outer integument of the fertile ovule.

The morphology of the two sterile eyes varies from that of the fertile eye. The difference lies in the fact that, in the formation of the shell of the sterile eyes, tissues other than the outer integument of the fertile ovule and the palisaded layer of the endocarp take an active part.

Tangentially, the fertile eye (Plate 3, fig. 13) is a circular structure, at the periphery of which are located, vertically and obliquely, tubular cells of the endocarp (Plate 3, figs. 11 and 12).

Taxonomists generally regard the shell of the coconut as made up solely of the endocarp. Since not only the endocarp but also the outer integument of the seed contribute to the formation of

the stony layer, or shell, of the coconut, as a whitish yellow coating in the innermost portion of the shell, a discussion of the development of the latter becomes a necessity. This intimate relation of the outer integument and the endocarp was pictured by Winton.(13) The anatropous ovules at the basal portion of the ovary possess two coats, outer and inner integuments (Plate 2, fig. 4; Plate 3, fig. 15). These two coats in their juvenile stages are composed mostly of isodiametric cells, the peripheral cells of which are elongated and palisaded (Plate 3, fig. 15). As the ovules develop, vascular bundles are formed in only the outer integument (Plate 3, fig. 7). The cells of the inner integument remain small and isodiametric.

Only one of the ovules formed in the basal portion of the ovary becomes functional; the other two degenerate. As the fertile ovule develops and its embryo sac enlarges, it fills up one of the three loculi of the ovary. The other two loculi become compressed in the wall of the developing fruit. The outer integument of the fertile ovule and the endocarp of the pericarp wall come together (Plate 3, figs. 7 and 14). The two degenerated ovules, due to pressure resulting from the growth of the fertile ovule, are compressed also, and their cavities are reduced to lunar slits. Not only the outer integument of the fertile ovule, but also the outer integuments of the two degenerated ovules, come in contact with the endocarp.

Before the outer integument of the fertile ovule comes in contact with the endocarp of the pericarp wall, it consists mostly of isodiametric cells, small near the inner integument and increasing in size toward the periphery. The peripheral layer of the outer integument consists of palisaded to squarish cells. Vascular bundles are manifest (Plate 3, fig. 7). The inner integument consists of isodiametric cells of nearly uniform size, bordered by palisaded cells toward the embryo sac.

The outer integumental cells near the endocarp are larger and their walls very much thicker than either those in the middle of this integument or those toward the inner integument. Lignification of the outer integument precedes that of the endocarp. It begins at the apical region of the fruit and ends at the basal end and is, therefore, similar to that of the endocarp. As lignification proceeds to the basal end of the fruit, it progresses from the outer portion inward to the inner integument. However, at the fertile eye, lignification is seen first in the middle of the outer integument, and progresses simultaneously inward and outward

to the endocarp. With the exception of the cells bordering the micropyle of the fertile ovule, which are slightly lignified, lignification of the outer integument is rather homogenous throughout.

SUMMARY

The inflorescence of the coco palm begins as a protuberance at the axil of the petiole, at the base of which two primary bracts, outer and inner spathes, respectively, are cut off, the latter outgrowing the former as inflorescence develops. The main axis, rachis, then cuts off secondary bracts, at the axils of which primordia of the rachillæ (lateral branches) develop. The rachillæ, similar to the main axis (rachis), cut off bracts (tertiary bracts) at the axils of which the flowers arise.

The development of the female floral organs is centripetal, and is as follows: Scaly leaves, or bracteoles; sepals; petals; aril; and carpels.

The endocarp, which later constitutes the major portion of the stony layer, or shell, differentiates early; that is, before fertilization.

The stony layer is composed of the endocarp and the outer integument, as reported by Winton. The inner integument adheres to the endosperm as a thin brownish to reddish papyraceous coat.

Lignification of the endocarp proceeds from the stigmatic point of the fruit toward the basal region, and from the middle to the sides of the layer of the endocarp. Cell lignification is similar to that in *Sassafras sassafras*.

Lignification of the outer integument also proceeds from the stigmatic point of the fruit toward the basal end, and from the outer portion inward toward the inner integument. In the fertile eye, it is visible first at the middle and proceeds to the sides of the outer integumental layer. It precedes that of the endocarp.

The stone cells of the endocarp are greatly lignified and present a variety of forms. The cells of the outer integument are also lignified, but less so than the cells of the endocarp.

The depression at the eyes is due to the fact that most of the endocarp cells in the region do not lignify. Less tissue participates in the formation of the stony layer of the functional eye than in that of the other two eyes.

ACKNOWLEDGMENT

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ILLUSTRATIONS

Plate 1. The Coco Palm

Fig. 1. Portion of the spadix showing the rachis (*ri*), rachilla (*ra*) with male (♂) and female (♀) flowers. ×0.5.

2. A single rachilla showing a basal female flower and male flowers. × 0.5.

3. Median longitudinal section of the whole inflorescence showing primary bracts or spathes (*c*) and the beginning of the inner spathe (*i*). × 22.

4. Tangential longitudinal section of the whole inflorescence showing the outer spathe (*os*) and the inner spathe (*is*). × 22.

5. Median longitudinal section of the whole inflorescence showing the spathes (*os* and *is*) and the rachis giving rise to lateral secondary bracts (*sb*). × 22.

6. Median longitudinal section of the rachis showing the basal secondary bracts during rapid elongation (*sb*). × 22.

7. A much advanced stage of the development of the secondary bracts. × 22.

8. Longitudinal section of the rachis showing the primordia (*p*) of the rachillæ emerging from the axils of the secondary bracts (*sb*). × 22.

9. Portion of a longitudinal section of the rachis showing the rachilla (*ra*) already developed and differentiated. × 22.

10. Portion of a longitudinal section of a rachilla showing tertiary bracts (*tb*). × 22.

11. A longitudinal section of a much older rachilla showing the floral primordia (*p'*). × 22.

Plate 2. The Coco Palm

Fig. 1. A portion of the base of the rachilla showing three developed female flowers with the lateral male degenerated flowers darkened. × 0.5.

2. Lateral view of the female flower showing the petals (*pt*) and sepals (*s*). × 0.5.

3. Cross section of the ovary to show the position of the ovules. Inner integument (*ii*), outer integument (*oi*), nucellus (*n*). × 30.75.

4. Longitudinal section of the ovary to show the anatropous ovules. × 30.75.

5. Longitudinal section of the young female flower showing the two scaly leaves (*sl*) and the beginning of the sepals (*s*). × 30.75.

6. Longitudinal section of an older female flower with the tertiary bracts (*tb*), scaly leaves (*sl*), sepals (*s*), and petals (*pt*) developing. × 41.5.

FIG. 7. Longitudinal section of a much older female flower, showing the perianth segments already developed. × 22.

8. Longitudinal section of a female flower with the aril (*a*) and with carpel (*a'*) walls already formed. × 22.

9. Longitudinal section of one of the anatropous ovules, showing the outer and inner integuments. × 65.5.

FIGS. 10 to 16. Diagrammatic drawings, showing the development of the fruit. × 0.25.

PLATE 3. THE COCO PALM

FIGS. 1 to 5. Diagrams of the longitudinal sections of the fruits, showing the trend of lignification. Basal end (*mi*), stigma (*st*), apical end (*ch*), inner integument (*ii*), outer integument (*oi*), endocarp (*en*), exocarp (*ex*), and mesocarp (*m*). ×0.125.

FIG. 6. Longitudinal section of the pericarp wall, showing triple differentiation of the pericarp into exocarp (*ex*), mesocarp (*m*), and endocarp (*en*). × 196.5.

7. Portion of a longitudinal section of the side of the ovary and fruit, from the embryo sac to the mesocarp (*m*). Note the vascular bundles (*vb*) in the endocarp and outer integument. × 196.5.

8. Portion of the pericarp, showing exocarp (*ex*) and mesocarp (*m*) well differentiated. × 196.5.

9. Portion of the palisaded cells (*pa*) of the endocarp at the micropylar region of the ovule. × 196.5.

10. Diagram of a longitudinal section of the endocarp and portion of the outer integument attached. × 72.25.

11. A strip of the tangential section of the eye from the micropyle to the endocarp, taken as shown in figs. 12 and 13. × 42.5.

12. Diagram of a radial section of the fertile eye, showing the inner integument (*ii*), outer integument (*oi*), palisaded cells of the endocarp (*pa*), and the endocarp (*en*). × 14.

13. Diagram of a tangential section of the fertile eye taken from the portion indicated in fig. 12. × 14.

14. Longitudinal section of a portion of the ovary, showing the integuments of the ovule still away from the endocarp (*en*), and the loculi (*li*) still present. × 196.5.

15. Longitudinal section of the anatropous ovule, showing the structure of the integuments. × 42.5.

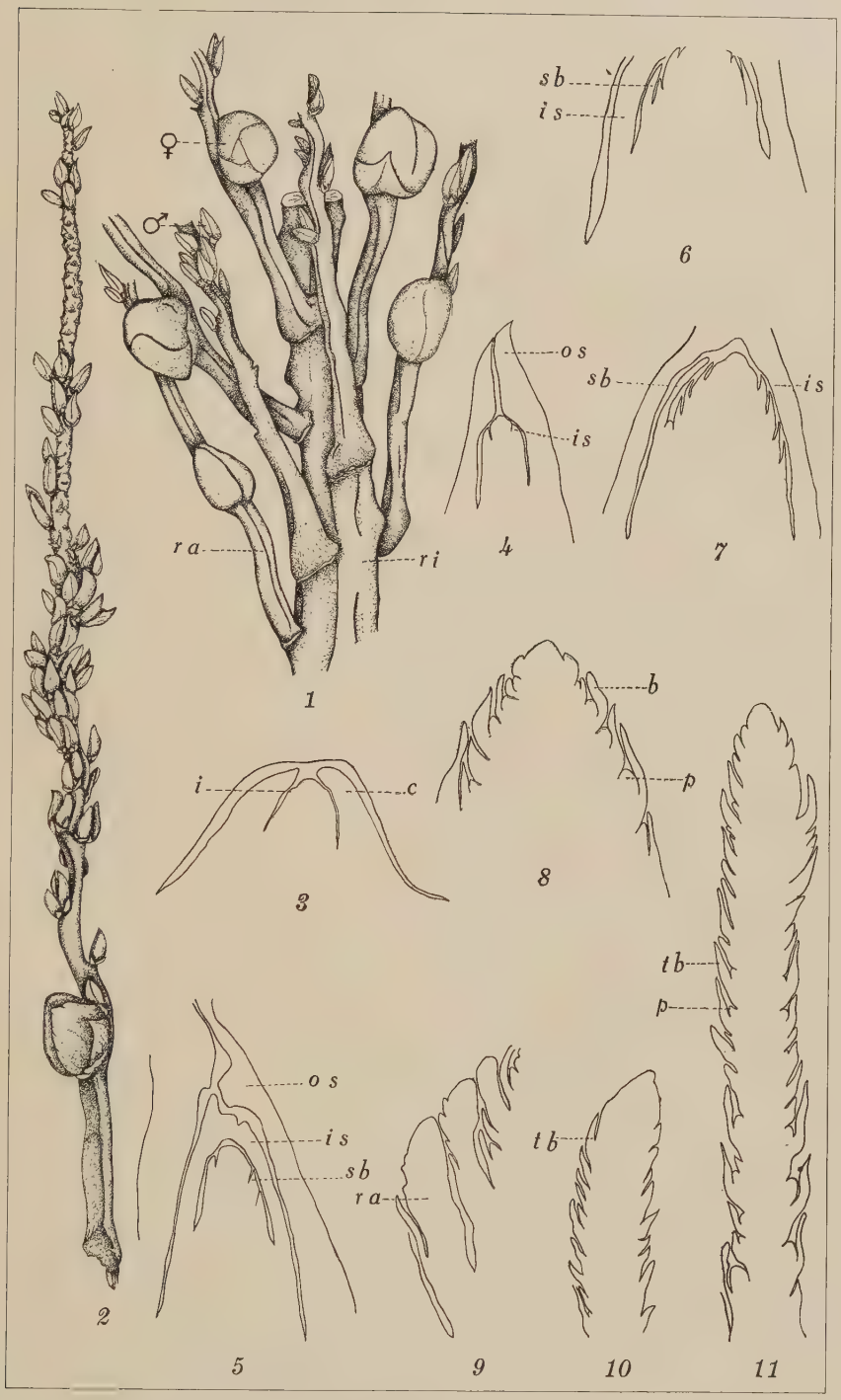
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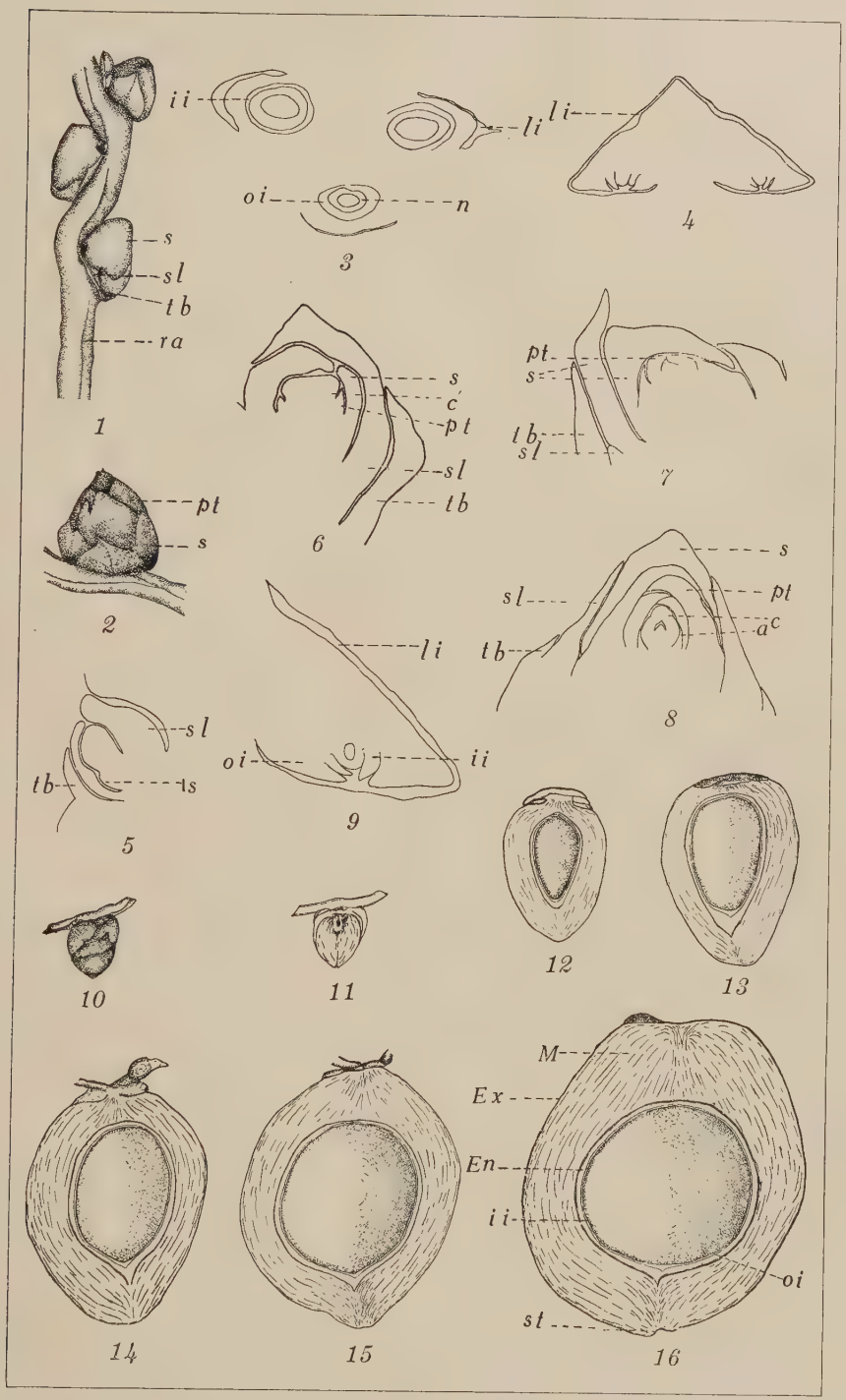
PLATE 1.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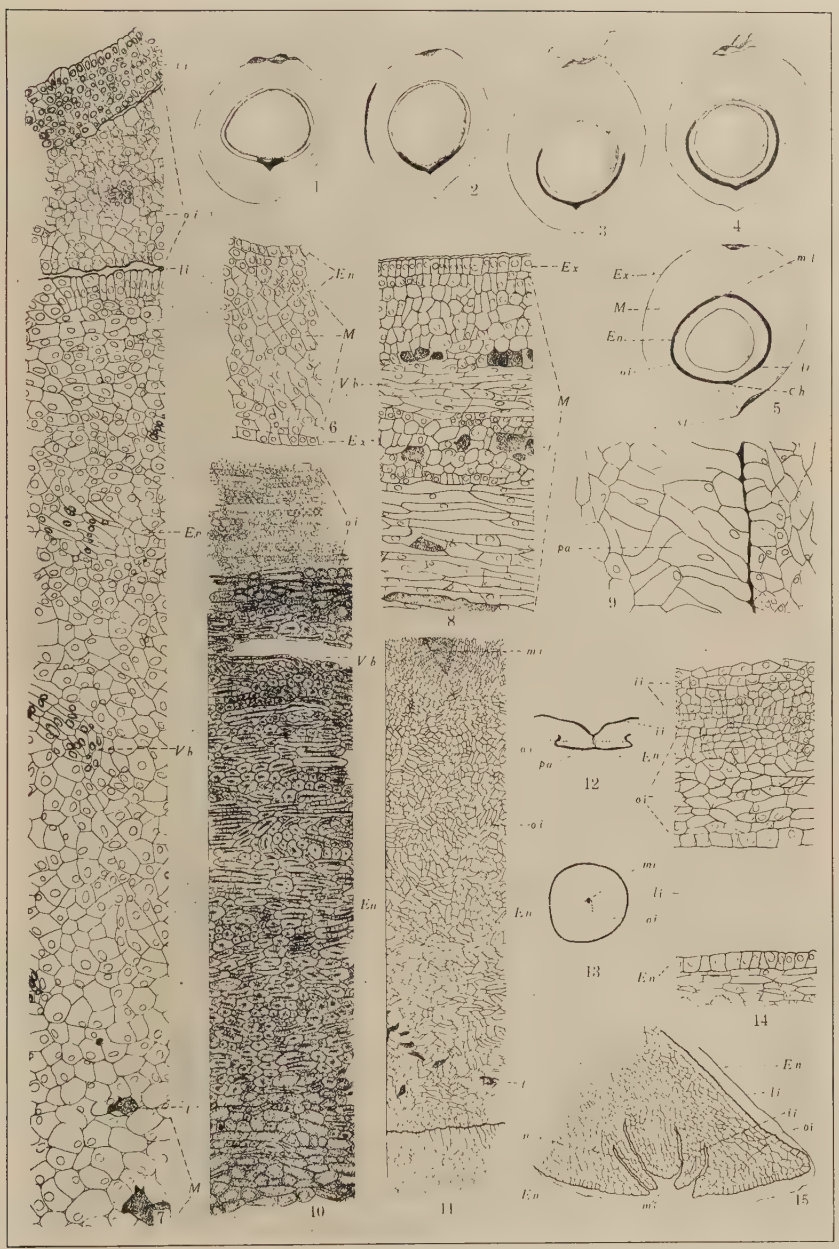

PLATE 3.

THE DEODORIZATION OF COCONUT OIL

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INTRODUCTION

At the present time there is only one company in the Philippines engaged in the manufacture of refined deodorized coconut oil. This company uses the oil for making a lard compound, a coconut margarine, and a milk. The oil, after having been heated, is deodorized in 5-ton lots by blowing superheated steam through it in small streams under a vacuum. The vacuum is obtained by means of a barometric head. The vacuum and temperature, as well as the supply of steam, vary slightly during the operation; but the attempt is made to hold the temperature around 177 to 248° C. (350 to 400° F.) and the vacuum at 25 inches. The time of deodorization is usually nine to ten hours.

The substances that are volatile with steam are condensed and are carried along with the water which is passed through the barometric head to generate the vacuum. This water, heated slightly by the condensed vapors, together with the volatilized products is run into a large rectangular trough about 1.2 meters deep, where some of the volatilized products separate, rise, and float on the surface of the water. By placing a board over the outlet of the trough, the water can be made to flow out of the trough from underneath the surface. In this way, the water-insoluble products that are removed by this refining process can be collected. The product, as skimmed from the surface of the water, is a whitish or grayish, greasy, malodorous substance that slowly turns darker on exposure to air. In appearance it resembles vomitas more than anything else. It has a sour, acid odor coupled with a heavy, unpleasant, very persistent, somewhat aromatic one. The latter odor is especially noticeable in the deodorization room as soon as the process of of deodorization is begun, and resembles the odor in a bodega where copra has been stored for some time.

The deodorization sludge changes in appearance as the operation proceeds. At first it is an oily liquid with a very greasy

feel. After about three hours' operation, solid white particles begin to appear and the substances now cover the surface of the water in the tank with a solid whitish scum. As the end of the deodorization is approached, the solid, tallowy, whitish substance predominates and the characteristic ketonic odor is barely perceptible.

The volatilized products were collected in five fractions to determine if the nonsaponifiable constituents came over mostly at the beginning or at the end of the operation. The material was skimmed from the surface and the water allowed to drain from it through filter paper, and it was then weighed while moist. It was then taken to the laboratory, saponified and steam-distilled, and the amount of nonsaponifiable matter was determined. The results of these determinations appear in Table 1.

TABLE 1.—*Nonsaponifiable content of the different fractions.*

Fraction.	Time of collection.	Weight of moist sludge.	Yield of nonsaponifiable substances.
		g.	*cc.*
1	7 a. m. to 9 a. m	512.0	54.0
2	9 a. m. to 11 a. m	510.0	98.5
3	11 a. m. to 2 p. m	2,087	52.0
4	2 p. m. to 4 p. m	2,476	10.0
5	4 p. m. to 5.30 p. m	1,065	4.0

A total of 218.5 cubic centimeters, or 179.17 grams, of nonsaponifiable substances was recovered from the 5 metric tons of coconut oil that had been placed in the deodorizer. This amount corresponds to a yield of 0.0036 per cent. This percentage of course does not represent the amount present in crude coconut oil, because a large amount is carried away with the tremendous quantity of water used to generate the vacuum during the nine to ten hours of operation. None of this water is used over again, because the colder the water, the more effective the operation of the barometric head.

The yield of the nonsaponifiable constituents from crude coconut oil was determined in the laboratory by distilling some crude coconut oil with steam. This distillation was performed on 2 kilograms of oil at a time; the temperature of the oil was maintained around 120° C., and the steam passed into it for

four hours. The water that separated from the distilled oil was used again, to generate steam. The results are tabulated in Table 2.

TABLE 2.—*Laboratory yields of nonsaponifiable constituents from crude coconut oil.*

Oil used for distillation.	Free fatty acid of original oil (as oleic).	Total oil distilled and carried over mechanically.	Nonsaponifiable constituents.		Yield of nonsaponifiable constituents.
kg.	*Per cent.*	*cc.*	*cc.*	*g.*	*Per cent.*
36------	3.68	172	19.0	15.9	0.0441
44------	2.15	200	21.3	17.9	0.0407

The amount of nonsaponifiable constituents obtained in this way is more than ten times that yielded when determined on the deodorization sludge as obtained from the plant, and confirms the supposition that much of the lower-boiling material is lost in the water used to generate the vacuum. The nonsaponifiable constituents recovered from the crude oil in the laboratory ought to contain a larger proportion of the lower-boiling, more water-soluble, odorous components than that obtained from the deodorization sludge of the factory. This supposition is verified by comparing Tables 3 and 5. Thurman [1] gives 0.40 per cent as the volatile water-soluble loss when coconut oil is deodorized. Salway [2] gives 0.03 per cent as the yield of neutral oil obtainable from coconut oil. By an examination of Table 2, it will be observed that the higher yield of nonsaponifiable constituents is obtained from the oil that has the higher free fatty acid.

The deodorization sludge can be divided into three parts: acidic substances, saponifiable substances, and nonsaponifiable substances.

ISOLATION AND PROPERTIES OF THE SUBSTANCE

At the beginning of this work, I was not familiar with the article of Haller and Lassieur [3] and consequently started to work in a different way. The coconut deodorization sludge was treated with excess sodium hydroxide with thorough agitation until it was ascertained that saponification was complete. After

[1] Industrial and Engineering Chemistry 15 (1923) 397.
[2] Journ. Chem. Soc. 3 (1917) 407.
[3] Compt. Rend. L'Acad. Sci. 150 (1910) 1013.

standing overnight it was steam-distilled. A little calcium chloride was added to keep down the frothing.

Haller and Lassieur also neutralized with caustic soda but they then extracted with bisulphite. I decided to use the steam-distillation method, as originally planned, in the hope of perhaps obtaining other substances in the low- and high-boiling fractions besides those isolated by the authors mentioned.

The steam-distilled product was heated with fresh caustic soda for about one hour, and then washed with distilled water until the wash water was only faintly alkaline. The product secured in this manner was dried over calcium chloride for several days. It had the following properties:

Specific gravity at	25°C.	0.82316
	25°C.	0.82315
Refractive index at	25°C.	1.4312
		1.4312

This product is easily soluble in 95 per cent alcohol, ether, ethyl acetate, carbon bisulphide, chloroform, acetone, gasoline, or acetic acid. It is insoluble in water, dilute hydrochloric acid, dilute nitric acid, or ammonia. Concentrated nitric acid gives a reddish coloration.

The oil gave only a very slight optical rotation to the right.

The oil may be distilled under atmospheric pressure. The data from such a distillation, using 95 cubic centimeters, are presented in Table 3.

TABLE 3.—*Distillation of the oil.*

Temperature. °C.	Total distillate. cc.
217	(a)
227	5.0
230	25.0
233	50.0
235	60.0
239	70.0
241	75.0
248	80.0
261	85.0

[a] First drop.

This distillation shows that the middle fraction, boiling at from 227 to 235° C., constitutes the larger part of the oil. A vacuum distillation yielded the results shown in Table 4.

TABLE 4.—*Vacuum distillation of the oil.*

First trial.			Second trial.		
Total distillate.	Temperature.	Pressure.	Total distillate.	Temperature.	Pressure.
cc.	°*C.*	*mm.*	*cc.*	°*C.*	*mm.*
[a]	177	230	[a]	181	240
8.5	187	250	13.0	190	262
34.0	185.7	216	39.0	189	242
58.5	185.5	206	64.0	190	240
84.0	192.5	236	90.0	198	240
94.0	224.5	256	95.0	220	246

[a] First drop.

One hundred cubic centimeters of the substance were used for the distillation; 2.5 cubic centimeters were recovered in the distillation flask. The temperatures are uncorrected for exposed stem.

These distillations likewise show a large middle fraction boiling at around 185° C. under 210 millimeters pressure or, at 189° C., around 240 millimeters pressure.

If the distillation is performed under a higher vacuum (8 millimeters) such as is generated by a Cenco-Nelson pump, practically all of the low-boiling constituent is lost and condenses on the container before boiling begins.

The distillation of the nonsaponifiable constituents obtained from the 80 kilograms of crude coconut oil by steam distillation (see Table 2) after drying with calcium chloride, gave the results recorded in Table 5.

TABLE 5.—*Distillation of nonsaponifiable constituents secured from the laboratory deodorization experiments.*

Temperature. °*C.*	Distillate. cc.
0 to 195	[a]
195 to 205	0.5
205 to 210	1.5
210 to 220	10.5
220 to 230	19.0
230 to dryness	2.5

[a] One drop.

The nonsaponifiable part of coconut oil prepared in this way contains a larger proportion of lower-boiling constituents than does that prepared from the deodorization sludge obtained from the factory.

PREPARATION OF THE OXIME

The oxime may be prepared either in alkaline or in acetic acid solution. Twenty-two grams hydroxylamine hydrochloride and 44 grams of sodium acetate were dissolved in a little water in a flask, then 50 grams of undistilled ketone were added with a little 95 per cent alcohol to aid in bringing the ketone in solution. The contents of the flask were then boiled gently for one to two hours under a reflux. The reaction mixture, if allowed to cool, will separate into a lower aqueous layer, and an upper oily layer containing some crystals. The oxime is removed by ether extraction and washed with distilled water several times; then the ether is allowed to evaporate and the resulting oil is chilled in a refrigerator (9° C.). The crystals that separate are pumped from the oily mother liquor and recrystallized from aqueous alcohol. They melt at from 42.5 to 43° C. Haller and Lassieur give from 44 to 45° as the melting point of the oxime of methyl nonyl ketone. Because the oxime has so low a melting point it is rather difficult to recrystallize, as it melts and floats on the surface as an oil instead of dissolving.

After the identity of this ketone was definitely established by the preparation of ether derivative, the oxime was made of some of the fraction boiling at between 185 and 186° C. at 212 millimeters pressure. After it was recrystallized from aqueous alcohol once it melted at 43.5 to 44° C.

PREPARATION OF THE SEMICARBAZONE

Ten and seven-tenths grams of semicarbazide hydrochloride and 10.7 grams sodium acetate were placed in a flask with 20 cubic centimeters water, and then 20 cubic centimeters of undistilled ketone and 100 cubic centimeters of 95 per cent alcohol were added. This mixture was boiled with a reflux condenser until no more oil remained on the surface, and then three-fourths of an hour longer. When it was poured into a beaker of cold water a voluminous white precipitate formed which was filtered with suction, dried, and recrystallized from absolute alcohol. It consisted of beautiful white crystals which melted at 119° C. and remelted at 116° C. After recrystallization once from acetone and twice from absolute alcohol it melted at 120° C. and remelted at 116° C., which is in agreement with the findings of Haller and Lassieur for the semicarbazone of methyl nonyl ketone.

PREPARATION OF THE DIOXIME

To prepare the dioxime, 20 grams of the ketone were mixed with 8 cubic centimeters of concentrated hydrochlorine acid and cooled with ice; then 13.6 cubic centimeters of amyl nitrite were added, a small amount at a time. The mixture was shaken continuously and cooled so as to keep the temperature between 45 and 50° C. After all the amyl nitrite had been added, the reaction mixture was shaken for a half hour longer. Seventy-five cubic centimeters of a 2 per cent sodium hydroxide solution were now added to the product in a separatory funnel, shaken, allowed to separate, and then the lower alkaline layer drawn off. This operation was repeated six times. The sodium hydroxide fractions were distilled with steam a short time only, to remove amyl alcohol, because mononitroso methyl nonyl ketone is also rather volatile with steam. The amyl alcohol cannot be removed by ether extraction as Adams and Kamm [4] recommend in their directions for the preparation of dimethyl glyoxime, because the nitroso compound of methyl nonyl ketone is extracted from an alkaline solution by ether. [5]

By heating the alkaline solutions with hydroxylamine solution in an open beaker in a draft of air the amyl alcohol is also easily vaporized.

These steam-distilled residues were then treated with hydroxylamine hydrochloride which had been neutralized to litmus. A slightly discolored whitish solid began to separate at once. This mixture was heated on the hot plate for a half hour longer to complete the reaction, then allowed to cool, filtered, and recrystallized from aqueous alcohol. The slightly yellowish crystals obtained melted at 159° C. When this substance was washed with petroleum ether to remove monoxime, diketone, and monoketone, and then recrystallized again from hot aqueous alcohol, it melted at 161 to 162° C. Filetí and Ponzio give 162° C. as the melting point of this dioxime.

During the heating of the isonitroso ketone with the hydroxylamine solution, a pinkish color developed in the solution similar to that which occurs when dimethyl glyoxime is prepared by Adams and Kamm's method.

If the temperature of the reaction mixture of ketone and hydrochloric acid is allowed to rise to 55° C. during the addition

[4] Journ. Am. Chem. Soc. 40 (1918) 1287.
[5] Filetí and Ponzio, Gaz. Chim. Ital. 24 [2] (1894) 294.

of the amyl nitrite, a gas is generated in considerable amount and a yellowish oil is produced. This oil when heated with hydroxylamine also yields the dioxime. The ketone has probably been oxidized according to the following equation: [6]

$$CH_3COCH_2C_8H_{17} + C_5H_{11}NO_2 = CH_3CO\ C\text{-}NOH\text{-}C_8H_{17} + C_5H_{11}OH$$

$$CH_3CO\ C\ NOH\ C_8H_{17} + C_5H_{11}NO_2 = CH_3CO\ CO\ C_8H_{17} + C_5H_{11}OH + N_2O.$$

When the percentage of nitrogen in the dioxime was determined by Dumas's method the following results were obtained:

TABLE 6.—*Determination of nitrogen in the dioxime.*

Substance taken.	Moist nitrogen.	Temperature.	Pressure.	Nitrogen. [a]
g.	*cc.*	°*C.*	*mm.*	*Per cent.*
0.2024	24.6	30	759.5	13.11
0.2614	32.3	30.5	758.5	13.27

[a] Theory requires 13.08 per cent nitrogen.

The nonsaponifiable part of the deodorization sludge also contains some alcoholic constituents. These may be isolated by heating with phthalic anhydride, as Haller and Lassieur direct.[7] The product obtained by following their directions is a white glycerinelike substance with an odor somewhat similar to that of octyl alcohol. It is more soluble in water than methyl nonyl ketone but is still sufficiently insoluble so that it can be separated from the phthalic anhydride saponification product by steam distillation. It is optically active and rotates the plane of polarized light to the right. Haller and Lassieur state that this product consists of methyl *n*-heptyl and methyl *n*-nonyl carbinols.

The same authors have isolated methyl *n*-heptyl ketone from the lighter fraction and methyl *n*-undecyl ketone from the higher fraction of the nonsaponifiable part of the deodorization product. The first odor that issues from the end of a Liebig condenser when coconut oil is distilled with steam resembles that of an amyl compound. It is the same volatile, rather fragrant odor that is noticeable when one enters a copra bodega. However, no oil boiling around 152° C. could be isolated, although some oil can be obtained boiling around 195° C. and 263° C.

[6] Meyer and Jacobson, Lehrbuch der organischen Chemie, 2d ed. 1 [2] 824.
[7] Compt. Rend. L'Acad. Sci. 151 (1910) 697.

ANALYSIS OF THE ACIDIC AND SAPONIFIABLE CONSTITUENTS

This analysis was made on two samples collected about one month apart. The first sample represents the last two hours of deodorization, and the second sample the last four hours. The samples were prepared for analysis by allowing the excess water to drain off; then the material was placed in a beaker and beaten with a stirring rod until no more water could be obtained by slightly inverting the beaker.

METHODS OF ANALYSIS

The percentage of water was determined by the method described by Dean and Stark,[8] using 20 cubic centimeters of benzene and 80 cubic centimeters of xylene and a 20-gram sample. The acidity was determined by dissolving the sludge in neutral alcohol and titrating while still warm with half normal sodium hydroxide, using phenolphthalein as indicator. Then excess alkali was added and the oil saponified in the usual way by boiling and titrating the excess alkali with half normal acid. The ash was determined by placing about 10 grams of the sludge in a small porcelain dish, heating slowly until all the water was driven off, and then igniting by stronger heating and applying a flame. When the fatty material was nearly all burned the dish was placed in the muffle furnace and the ignition completed. The results of the analysis are given in Table 7.

TABLE 7.—*Analysis of the deodorization sludge.*

Sample.	Trial.	Water.	Acidity as lauric.	Saponification No.	Ash.
		Per cent.	*Per cent.*		*Per cent.*
1	1	19.5	31.8	72.2	3.15
	2	20.0	31.5	78.1	3.37
2	1	21.0	20.7	84.8	
	2	20.5	21.3	81.0	

Qualitative analysis of the ash shows the presence of sodium, calcium, magnesium, chlorine, and sulphate. These substances come from the brackish water used to generate the vacuum. The sludge also contained a substance which was acetone insoluble and resembled a calcium soap.

Part of sample 2 was dissolved in carbon tetrachloride and sodium carbonate added in excess with considerable agitation; the excess sodium carbonate and the soap resulting from the neutralization of the free fatty acids were then filtered off and

[8] Journ. Ind. Eng. Chem. 12 (1920) 486.

the carbon tetrachloride was removed from the oil by distillation. The oil thus obtained was neutral and slightly darker than ordinary coconut oil. Two determinations of the saponification number gave 251 and 253.

DISCUSSION OF RESULTS

Ketones are much more widely distributed in nature than was formerly supposed. This is especially true of methyl nonyl ketone. No attempt will be made to mention all the oils in which it has been found. Salway [9] found it in palm oil. Thoms [10] and Houben [11] definitely identified it in oil of rue, and recently it has been detected in oil of jaborandi leaves.[12] The rôle that methyl nonyl ketone plays in plant metabolism is not yet definitely established. However, the presence of this ketone in coconut oil can be accounted for when we take into consideration the constituents of coconut oil and their properties.

The percentages of the fatty acids in coconut oil according to Elsdon [13] are as shown in Table 8.

TABLE 8.—*The fatty acids of coconut oil, according to Elsdon.*

	Per cent.
Caproic acid	2
Caprylic acid	9
Capric acid	10
Lauric acid	45
Myristic acid	20
Palmitic	7
Stearic	5
Oleic	2

If we accept these percentages as approximately correct and associate them with the fact that ordinary mold fungi resolve fats into free acid and glycerine and then oxidize the resulting fatty acid into the methyl alkyl ketone with one carbon atom less, we can readily see why we would find methyl nonyl ketone in the product obtained from the deodorization of neutral coconut oil.

Fierz-David [14] states that the reaction is one of oxidation and the same ketones are obtained as are obtained by the oxida-

[9] Journ. Chem. Soc. Transaction 111 (1917) 407.

[10] Chemisches Centralblatt 72 [1] (1901) 524.

[11] Berichte der Deutschen chemischen Gesellschaft 35 [3] (1902) 3587.

[12] Chemisches Centralblatt 95 [2] (1924) 893.

[13] Lewkowitsch, Chemical Technology and Analysis of Oils, Fats, and Waxes, 6th ed. 2: 656.

[14] Zeitschrift Angewandte Chemie (1925) 6; also Analyst No. 590 50 (1925) 244.

tion of the fatty acids by hydrogen peroxide and ammonia, according to the scheme of Dakin,[15] which is as follows:

$$R\,CH_2CH_2COOH \rightarrow R\,CH\,OH\,CH_2COOH$$
$$R\,CO\,CH_2COOH \rightarrow R\,CO\,CH_3 + CO_2$$

From the acids of coconut oil we would, therefore, expect to get the ketones listed in Table 9.

TABLE 9.—*Fatty acids and their corresponding ketones.*

Acid.	Ketone.	Boiling point of ketone.
		°C.
Caproic	$CH_3(CH_2)_2CO\,CH_3$	101.8
Caprylic	$CH_3(CH_2)_4CO\,CH_3$	151-152
Capric	$CH_3(CH_2)_6CO\,CH_3$	195
Lauric	$CH_3(CH_2)_8CO\,CH_3$	231.5-232
Myristic	$CH_3(CH_2)_{10}CO\,CH_3$	263
Palmitic	$CH_3(CH_2)_{12}CO\,CH_3$	294
Stearic	$CH_3(CH_2)_{14}CO\,CH_3$	319-320

One would expect to get very little methyl propyl or methyl amyl ketone, because of the low percentages of caproic and caprylic acids in coconut oil and the manner in which the oil is expressed from the copra where a temperature of 110 to 120° C. would be sufficient to volatilize the propyl and amyl ketones, especially when we consider that considerable water (5 to 6 per cent) is also volatilized at the same time by this treatment.

The quantity of tridecyl or pentadecyl ketone would likewise be small, because of the low percentage of the parent acids. The yields of the lower molecular weight ketones would also be less, due to their greater solubility in the water employed to generate the vacuum. From the distillation temperatures of the nonsaponifiable fraction of the deodorization product, methyl nonyl and methyl undecyl and methyl heptyl ketones should be present in the greatest amount. This is what one would expect from the percentages of lauric, myristic, and capric acids in coconut oil.

Methyl heptyl carbinol and methy nonyl carbinol no doubt arise from the reduction of the corresponding ketones, since Neuberg and Nord[16] found that this reduction may take place either photochemically or biochemically.

[15] Am. Chem. Journ. 44 (1910) 41.
[16] Report, Schimmel & Co. (April-October, 1920) 134.

SUMMARY

1. Methyl nonyl ketone was isolated from the product obtained from the deodorization of coconut oil, thus confirming the finding of Haller and Lassieur.

2. Its presence is established by the preparation and identification of the oxime, dioxime, and semicarbazone.

3. Most of the nonsaponifiable substances distill over in the first four hours of deodorization.

4. The yields of the nonsaponifiable constituents obtained from crude coconut oil in the laboratory and from the condensed deodorization sludge that was obtained from the factory are given.

5. The nonsaponifiable constituents also contain alcoholic compounds.

6. Two analyses of the crude acid sludge are given.

MINERAL CORDAGE OILS

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INTRODUCTION

Abacá (Manila hemp) and abacá products constitute the third most important item of export from the Philippine Islands; in 1924 the exports amounted to 63,893,928 pesos. Since 1909 rope has been manufactured in the Islands in a factory equipped with modern machinery. At the present time there are five such rope factories in the Philippine Islands; they were equipped or incorporated in 1909, 1911, 1917, 1923, and 1924.

The Bureau of Science is occasionally called upon to analyze oils for cordage purposes which are submitted by competing salesmen, and to express an opinion on their relative value. Without definite specifications as a guide this is no easy matter. This lack of specifications prompted me to collect and publish what is known and thought about cordage oils and generally practiced in the Philippines, the hemp center of the world. This paper is a compilation of information gathered from manufacturers, from technical men engaged in the industry, from oil salesmen, and from personal observation. Many extreme opinions are omitted and this paper could very appropriately be called a résumé.

THEORETICAL CONSIDERATIONS

There are two main theories as regards the use of cordage oil; namely, it serves as a lubricant for the fibers during the process of manufacturing the rope and, subsequently, during the life of the rope. There must be sufficient lubrication so that the fibers will not become heated or worn. The other theory is that the oil serves as a medium for the dispersion of the fillers used in manufacturing the rope and displaces water in the fiber, thus preventing decay, mold, and deterioration. The oil soaks into the sclerenchyma fiber and the filler is deposited on the outside of the fibers where it lubricates the small filaments which constitute the rope. The latter theory seems to have some justification, for an ordinary dry rope will start to "drop" oil when it

is stretched to about 80 per cent of its tensile strength in a testing machine.

It is often claimed that the best rope ever made was treated with a fish oil. From a theoretical viewpoint, the use of an animal or a vegetable oil is entirely different from that of a mineral oil. The high price of animal and vegetable oils is the principal factor which has forced the change to a mineral one. The slow hydrolysis of a nonmineral oil with the liberation of fatty acid and glycerine no doubt helps the rope maintain some desirable properties, because the fatty acids as they are formed in situ among the fibers "wax" the strands.

There is no "waxing" when a mineral oil is used; neither is there any hydrolysis. Furthermore, even though the mineral oil be too high in the homologous series to have noticeable antiseptic action on molds, it at least does not furnish food for their growth. These circumstances are especially applicable if the rope is made in the rainy season when the moisture content of the fiber is high and the oil penetration poorer than usual. At the present time in none of the factories is the fiber dried before oil has been applied.

Viscosity of oil.—There is a direct and intimate relationship between viscosity and penetration into the fibers. If the oil is applied hot an oil of higher viscosity can be used than if it is applied cold. A light medium oil is considered about correct if it has good penetration. If its penetration is not so good, a lighter oil, one having a Saybold viscosity of 100 at 100° F., is used. In the temperate zone, the cold test would be of some importance; but in the Philippines, where the temperature extremes are so close together (65 to 96° F.) it has very little significance.

Volatility.—When kerosene is used to thin out an oil so as to increase its penetration, great inconvenience may result. A rope made with a kerosene-thinned lubricant may lose as much as from 8 to 10 per cent in weight upon storage in a bodega or in transit to the purchaser, thus necessitating adjustment of weights and prices on the purchaser's books, so that the amount received at the warehouse will check with the amount shipped. When such an adjustment has to be made between seller and buyer, the relations are not always the most cordial, and the impression is made on the buyer that he is buying oil at the price of rope. He is willing to buy rope by the pound, but he does object to buying rope that is filled with oil which is evaporat-

ing. The volatility of the eight oils that I examined was determined by weighing approximately 10 grams into a No. 0 low form porcelain crucible and heating for three hours at 110° C., and reweighing after it had cooled in a desiccator. Loss in weight is computed to percentage and recorded as volatility loss. With a temperature variation of 3° C. in the Freas electric oven, fairly concordant results can be obtained, as the results of the volatility loss of the eight oils analyzed show (see Table 1).

TABLE 1.—*Volatility loss of oils.*

Oil No.	Trial—		Average.
	1	2	
	Per cent.	*Per cent.*	*Per cent.*
1	0.52	0.55	0.53
2	0.51	0.54	0.52
3	0.46	0.44	0.45
4	0.44	0.56	0.50
5	0.35	0.40	0.37
6	0.22	0.21	0.22
7	0.20	0.20	0.20
8	0.19	0.21	0.20

Acidity and sulphur.—The opinion of the trade is unanimous that mineral cordage oils should be free from acidity. The use of kerosene is objected to, not only because of its high volatility, but also because its use is likely to introduce acidity into the oil. Just what the real objection to acidity is, no one seems to know.

A high sulphur oil is considered objectionable, because it is thought that the sulphur in the oil becomes spread out into such thin layers on the fiber that it is oxidized to sulphuric acid, and that this then causes "pitting." [1]

Emulsifiability.—At the present time the emulsifiability tendencies of an oil play a very insignificant rôle in the selection of a rope oil; but where the rope is exposed to water, as in marine usage, this property assumes some importance. If the oil is easily emulsified it will soon be removed from the fibers and the rope will become dry, hard, and heated in use. It will then rapidly deteriorate by molding and rotting. This point is just now beginning to be considered. Some marine ropes have failed

[1] The appearance of small darkish spots in the rope accompanied by a considerable decrease in tensile strength.

in use, but whether the cause of failure was due to the kind of oil or to the particular fiber used is yet undetermined. The emulsifiability of the oil is offered as a possible explanation.

The emulsifiability of the eight oils under study was determined by Test No. 27 of the New and Revised Tag Manual for Inspectors of Petroleum,[2] page 100, to see if there was much difference between them. The results are reported as R. E. number, A. S. T. M. method. The results of analysis are given in Table 2.

TABLE 2.—*The R. E. number of the cordage oils, by the A. S. T. M. method.*

Oil No.	Trial—		Approximate average.
	1	2	
	Per cent.	*Per cent.*	*Per cent.*
1	4.0	4.0	4.0
2	4.0	5.0	4.5
3	7.0	6.5	6.5
4	5.0	5.0	5.0
5	5.0	6.5	6.0
6	4.0	5.0	4.5
7	7.5	8.0	7.5
8	7.0	6.5	7.0

Inspection of Table 2 shows that there is really little difference in the R. E. number of the oils offered to the Manila market.

Color.—A dark oil cannot be used for a light-colored rope; except for this restriction, color plays an insignificant rôle in the choice of a cordage lubricant. The opinion is general in the Philippines that only paraffine-base oils are used in the Eastern States for cordage purposes. This is supposed to account for the development with age of the desirable yellow color in the rope instead of the grayish or blackish color imparted when an asphaltum-base oil is used. The cost of transportation favors a California or Singapore refined oil for use in the Philippines.

Flash and fire points.—These physical constants have no real significance, except as they affect volatility and increase the fire hazard when the oils are applied hot.

Fillers, waxes, and nonmineral oils.—For the dispersion of fillers, such as talc, graphite, kaolin, etc., one oil is as good

[2] C. J. Tagliabue Mfg. Co., 18–88 Thirty-third Street, Brooklyn, N. Y.

as another. Animal or vegetable oils, degras, wool grease, paraffine wax, fish oil, etc., at least within the limits desired in practice, are as soluble in one mineral oil as in another. Talc is sometimes used to prevent "squeak" (a cracking noise when the rope is held tightly in the hands and bent). Some buyers demand a rope without a "squeak." They claim that it wears better, especially for heavy use over pulleys. Other buyers, as the Java trade, demand a rope with a "squeak." Sometimes an oil high in free fatty acid is mixed with a mineral oil and then neutralized with caustic soda, and this mixture of oil, soap, and water is used as a rope oil. It is claimed that it also prevents "squeak."

FINANCIAL CONSIDERATIONS

The determining factor in the selection of a cordage oil is price; all other considerations are secondary to it. When the price per kilogram of fiber is 40 centavos, that of tallow 25, and of degras oil 20, a mineral cordage oil ought to be purchasable for 15 centavos a kilogram. An oil, to be considered, must be available in sufficient quantities, and the supply must be steady, so that the process need not be changed by the use of a substitute oil pending the arrival of a shipment of the oil regularly used. The oil must be uniform in quality, to insure uniformity in manufacturing the rope. Other things being equal, an asphaltum-base oil is given the preference over a paraffine-base oil, because of the higher specific gravity of the former. A good fiber will absorb 22 per cent by weight of oil. The quantity of oil that a fiber will absorb depends on the season of the year or the water content of the fiber. A fiber that will absorb 14 per cent by weight of oil in the wet season can be easily made to absorb 16 to 18 per cent in the dry season. It can be readily seen that a manufacturer will favor a high gravity oil, which he can purchase at 15 centavos and sell for the price of rope. This, however, is a minor consideration, but one which nevertheless exerts some influence in the selection of a rope oil. Where rope is bought on specification, the rope of course cannot contain more oil than the specifications allow, usually 8 to 12 per cent.

METHOD OF APPLICATION

The oil is applied either hot or cold by spraying it on the hanks as they go to the combing machines. When the oil is applied

hot, it is applied at 130 to 150° F. Some manufacturers believe a hot oil penetrates better, especially when the fiber is moist, as in the rainy season, and also that the hot application of an oil helps prevent "squeak."

ANALYSES OF OILS OFFERED IN THE MANILA MARKET IN 1925

The eight oils were analyzed according to the regular procedure in mineral-oil analysis. The data are given in Table 3.

TABLE 3.—*Analyses of oils offered to the Manila market in 1925.*[a]

Oil No.	Specific gravity at 60° F.	Viscosity Saybolt, at 100° C.	Flash and fire points (Cleveland open cup).		Sulphur.	Volatility loss.	R. E. No.
			Flash.	Fire.			
			°F.	°F.	*Per cent.*	*Per cent.*	
1	0.919	107	311	358	0.18	0.53	4
2	0.923	105	315	354	0.35	0.52	4.5
3	0.916	98	307	351	0.40	0.45	6.5
4	0.923	102	316	356	0.50	0.50	5.0
5	0.916	96	316	356	0.40	0.37	6.0
6	0.938	132	336	392	0.21	0.22	4.5
7	0.888	91	343	390	0.36	0.20	7.5
8	0.940	146	343	395	0.21	0.20	7.0

[a] Oils 5, 6, 7, and 8 were used in largest quantity.

SUMMARY

1. A résumé of the theories, ideas, opinions, facts, and practices regarding the selection and use of mineral cordage oils in Manila is given.

2. The analyses of the mineral cordage oils offered to the Manila market by jobbers in the early part of 1925 are also given.

Acknowledgment is hereby made to Mr. E. F. Gutierrez, of the Bureau of Science, who determined the sulphur in these oils; to the various oil companies who kindly furnished me with samples of their oils; and to various members of the cordage trade who gave me information and assistance.

BLOOD-CHEMISTRY STUDIES IN LEPROSY [1]

I. NONPROTEIN NITROGENOUS SUBSTANCES, SUGAR, AND CHLORIDE

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Despite the large amount of work that has been done on the chemistry of the nonprotein constituents of blood in various diseases, especially nephritis, in connection with which blood-chemistry studies have been considered to be of great importance by various investigators, no work on the blood analysis of lepers seems to have been done.

In 1922 when injections with chaulmoogra-oil derivatives were extended to all possible cases at Culion, it was found that tuberculous and nephritic lepers were unsuitable, continued application of the treatment having been found to be detrimental if not disastrous to such patients. The following year, Dr. Eloy V. Pineda,(8) assistant pathologist at Culion Leper Colony, basing his conclusions on three hundred autopsies performed by him, reported that nephritis was a common occurrence in the colony and that it stood second in frequency in causing death among the inmates. According to him it appears also that anti-leprosy drugs given to the afflicted persons cause kidney impairment, as indicated by the findings in urinalyses carried out in the Culion pathological laboratory in which, out of 1,120 specimens of urine examined, 95 per cent were positive for albumin and 88 per cent contained casts. In view of the foregoing and of the importance now attached to the chemical analysis of blood, which appears to be rapidly overshadowing the importance formerly attached to urinalysis, it is evident that a chemical investigation of blood constituents in lepers is a study which should no longer be neglected.

As a preliminary paper, the present report constitutes a comparative quantitative study of certain blood constituents;

[1] Read at the meeting of the Culion Medical Society, May 29, 1925. Published with the approval of the Director of Health.

namely, nonprotein nitrogen, urea nitrogen, uric acid, preformed creatinine, sugar, and chloride in the blood of one hundred lepers and of seventeen normal persons. The normal individuals from whom blood was taken were nonlepers from among the laboring class and the professional staff, who were presumably normal. The lepers' blood was taken from cases in the general hospital, in the dispensary, and in the treatment clinics. For certain reasons many hospital patients who had lepra reactions or nephritis were taken for examination.

The immediate object of the present report is the accumulation of data that will show the extent of retention of body metabolic products in lepers, with the added purpose of determining the relationships of these data to urinary findings, to the condition of leper patients, to the antileprosy treatment, and to duration of the leprosy. Among other clinical factors that should be thoroughly studied and correlated are types of leprosy, diet, and drug therapy. Discussion of these is not included in the present paper since it is understood that they will be reported by the physicians in charge of the patients.

For obvious reasons, the data that have been collected for lepers were arranged under five general headings (see Tables 3, 4, 5, 6, and 7), the groupings being based upon the condition of the subjects at the time the blood was drawn from them. Thus, Table 3 presents cases (mostly of the mixed type) without complications or the less commonly occurring symptoms. In Table 4 were placed the cases with miscellaneous complications, or special symptoms not shown by the cases presented in Table 1, such as malaria, ulcers, neuralgia, etc. Table 5 is of lepers with tuberculosis. Table 6 includes cases with lepra reaction but without nephritis. Table 7 shows cases with nephritis, presenting clinical symptoms.

It will be noted from the accumulated data that the uric acid determination was omitted in most cases; the omission is due to the fact that the method used for this determination during the early portion of the work gave unreliable results. In the latter part of the work Benedict's method(1) was used.

METHODS EMPLOYED

Blood specimens were drawn either before breakfast or three and a half hours later and were worked up as soon as possible to avoid any chemical change taking place. In view of the fact

that practically all data on normal standards and pathologic changes reported in the literature were obtained with blood taken before breakfast, it might be supposed that the values I obtained with blood taken three and a half hours after breakfast would not give comparable values. However, variations in concentration of the various constituents of blood taken before breakfast and of that taken three and a half hours after eating were thoroughly studied by Hammett,(6) who found practically no difference. Furthermore, the usual Culion breakfast is light, and Dr. H. W. Wade, chief pathologist, states that samples taken as early as 9.30 a. m. give sera that rarely show distinct digestive (lipoid) clouding.

Blood samples were conveniently collected in test tubes (100 by 25 millimeters) to which 1 cubic centimeter of 2 per cent sodium oxalate solution dried in an oven had been added. Prepared in this way the sodium oxalate in the tubes seemed to serve as an anticoagulant better than in any other yet tried.

Among the anticoagulants I have employed lithium oxalate in the form of cloth, as suggested by Otto Folin in his latest manual, seemed to have no advantage over other oxalates, such as potassium and sodium. On the contrary, unless the lithium oxalate solution saturated the cloth very thoroughly and the drawn blood was shaken vigorously, coagulation was hardly preventable. The objection to the use of potassium oxalate powder is that it causes precipitate formation in the colorimetric uric acid determination.

In the main, the technic of Otto Folin and Wu(2) was closely adhered to. For preliminary removal of proteins, whole blood (7 cubic centimeters was usually sufficient) was laked with seven volumes of distilled water in a 250-cubic centimeter Erlenmeyer flask. Then one volume of 10 per cent sodium tungstate was added. The whole contents of the flask were thoroughly mixed, after which one volume of two-thirds normal sulphuric acid was introduced, the flask being constantly shaken while the acid was added slowly, so as to prevent any clumping of proteins. The whole contents were filtered, the filtrates being invariably water clear and neutral to Congo red. The importance of checking up the quality of sodium tungstate and of having a correct two-thirds normal sulphuric acid for blood protein precipitation in order to obtain blood filtrates suitable for subsequent analysis of various blood constituents was em-

phasized by Otto Folin in 1922. From the blood filtrates, the determination of various blood constituents was made; for non-protein nitrogen, urea nitrogen, preformed creatinine, and sugar, the method of Folin and Wu(2) was followed. For the uric acid determination the new method of Benedict was used. Fleming, the only investigator, so far as I am aware, who has made blood analysis of Filipinos, used the same method. One reason for selecting Benedict's method was that precipitation, decomposition, and transfer of the final solution are eliminated, which otherwise would theoretically tend to cause slight loss. His method is simpler and permits more accurate colorimetric comparison than does Folin's. It might be stated that the reliability of results from the use of the latter method has been a matter of controversy recently between these two eminent biochemists. The method of Benedict seems, however, to have been the choice of many investigational workers on blood.

For the determination of urea, the urease-aëration method of Folin was followed, this having been found convenient for making several determinations at a time. In this method, urease paper instead of the alcohol jack-bean extract, as formerly adopted by Folin, was employed.

Quantitative determinations were sometimes run in duplicate and sometimes in triplicate. Analyses were repeated in all cases where there was the slightest doubt of the accuracy of the results. In a few cases showing unusually high values, a second analysis was made of the blood from the same patient, collected at a later date. No significant change was noted in these cases. Whole blood was used for all the determinations.

REAGENTS

All of the chemicals used in the analyses were of the highest grade of purity. The uric acid standard solution and 5 per cent sodium cyanide were prepared fresh at least once a month, and the standard sugar solutions, except the stock, were changed once every two weeks. Other standard solutions and reagents seemed to keep indefinitely.

In the nesslerization process, unless the Nessler reagent is correctly prepared, turbid solutions are formed when added to solutions containing ammonia. Folin remarked that Stand-

fords in 1923 stated that "No condition could be discovered in which clear solution could be obtained by direct nesslerization as suggested by Folin." He added that Cole in 1920 stated also that he was unable to repeat his experiments because of the turbidity of the resulting solutions. The main difficulty which they encountered lies undoubtedly in the percentage or amount of alkali used in nesslerization. At the start of this work I studied the cause of turbidity, which I also experienced, and found that by having an exact 10 per cent solution of sodium hydroxide accurately titrated, the turbidity when added to ammonia solutions was avoided and that the Nessler solution itself never separated as much green precipitate as is usually produced when it is incorrectly prepared.

PRESERVATION

Blood filtrates which were examined the day after the blood was drawn were preserved with 1 drop of toluene and kept in the refrigerator.

APPARATUS

All comparisons were made in a 5-centimeter Duboscq colorimeter. All apparatus used was chemically cleaned. All pipettes were calibrated to deliver.

BLOOD FINDINGS IN NORMAL INDIVIDUALS

As a basis of comparison and in order to check the technic followed, I examined the blood of seventeen presumably normal Filipinos (see Table 1).

In Table 2 the range of values in Table 1 is compared with the normal range as given by other investigators. It can be noted that the values representing the range within which the various substances were found to fluctuate, excepting the value for urea nitrogen, agree in general with the values found by Fleming.(3)

The difference in value for urea nitrogen may probably be attributed to the difference in technic followed, three methods having been adopted in the Folin-Wu system of blood analysis. Unfortunately, Fleming did not specify which of these methods he employed.

TABLE 1.—*Blood-chemistry findings in normal individuals.*

[Milligrams per 100 cubic centimeters of blood.]

Name.	Nonprotein nitrogen.	Urea nitrogen.	Uric acid.	Preformed creatinine.	Sugar.	Chloride (NaCl).
						Per cent.
G.	30.0	14.0		1.0		0.49
N.	25.5	18.0		1.5	80	0.49
D.	33.0	13.0		1.1	160	0.49
?	30.0	13.2		1.5	120	0.46
P. M.	25.5	12.7	3.6		102	0.47
I. O.	27.0	12.7	4.4		99	0.50
R. V.	31.5	16.0	3.0		102	0.45
G. H.	28.5	16.0	3.2		80	0.47
J. A.	30.0			1.5	80.3	0.49
D. A.	27.1	18.0	3.2	1.4	84.8	0.44
J. M.	32.0	11.4	2.9	1.4	85	0.44
J. R.	25.5	7.3	3.2	1.3	85.8	0.42
E. P.	25.5	13.5	4.0		95	0.49
M. C.	23.0	19.0		1.5	92	0.46
P.	27.0	12.7	4.4		99	0.46
P. C.	31.5	16.0	3.0		102	0.45
P.	28.5	16.0	3.2		80	0.47
Average.	28.3	14.3	3.5	1.2	96.7	0.46

TABLE 2.—*Normal ranges of blood chemistry as given by various investigators.*

[Milligrams per 100 cubic centimeters of blood.]

Author	Nationality studied.	Nonprotein nitrogen.	Urea nitrogen.	Uric acid nitrogen.
Gettler and Baker (4)	American	30–45	12–25	
Schamberg and Brown (9)	do	26–37	10–18	1.3–3.5
Gradwohl and Blaivas (5)	do	25–30	12–15	1–3
Squire, Bandler, and Myers (10)	do	25–35	12–15	2–3.5
McLean and Selling (7)	do	23–44	12–27	
Fleming (3)	Filipino	25–33.3	8.4–13	3.2–4.8
Paras	do	23–33	7–19	2.6–4.4

Author.	Preformed creatinine.	Sugar.	Chloride (NaCl).
			Per cent.
Gettler and Baker (4)		58–120	
Schamberg and Brown (9)	1–1.1	66–120	
Gradwohl and Blaivas (5)	1–2.5	80–120	0.65
Squire, Bandler, and Myers (10)	1–2.5	90–120	0.45–50
McLean and Se ling (7)			
Fleming (3)	1.3–1.5	93–160	
Paras	1–1.5	80–160	42–49

In general it may be noted that the agreement between my figures and Fleming's is much closer than that among the values reported by other investigators for normal white persons, as shown in Table 2. The variation as found by these investigators is not surprising, however, as there are numerous analytical methods of blood analysis available, some of which were worked out by the cited authors themselves.

BLOOD FINDINGS IN LEPERS

An inspection of Table 3, representing individual cases of leprosy without complication, shows that the values obtained were practically normal, except the nonprotein nitrogen values for cases 38, 42, and 94, which are above normal. Other cases, in which the leprosy shows the same or a greater degree of advancement, however, give entirely normal figures for nonprotein nitrogen. The extent of leprosy is stated in only about half of the cases. No records were available for the other cases because they were hospital patients not receiving antileprosy treatment. It appears, however, that chronic leprosy directly affects the concentration of blood constituents little, if at all, and that there is no regular correspondence between any of these constituents and the extent or type of the leprosy.

Table 4, representing cases of leprosy with miscellaneous complications, shows also essentially normal figures, except for cases 13, 31, and 72, which gave abnormal figures for nonprotein nitrogen.

In cases with tuberculosis (Table 5) the chemistry findings are practically normal, except in cases 19, 44, 64, and 65, which gave also abnormal figures for nonprotein nitrogen. Only case 68 showed abnormal figures for urea and uric acid.

In Table 6, cases with lepra reaction, the blood findings were in many cases above normal. The contrast with Table 3, showing chronic leprosy, is marked.

In cases of leprosy with nephritis (Table 7) the blood findings are typical of nephritis. The most significant findings are those in cases 25, 26, and 33. These patients have died since, and autopsy findings established uremia as the cause of death.

In studying the average data obtained for the various groups of cases (Table 8), it will be noticed that the average values for nonprotein nitrogen, uric acid, creatinine, and sugar are all somewhat higher in the leper groups than in the normal group, whereas the value for nonprotein nitrogen is especially high,

not only in the nephritis group as would be expected, but also in the group of patients with lepra reaction. The urea nitrogen is essentially normal in the first three leper groups, but this also is high, not only in the nephritis group, but also in the lepra reaction group. The chloride is normal throughout.

In Tables 3 to 7 the following abbreviations and symbols are used:

Sc = Slight, cutaneous.
Mc = Moderate, cutaneous.
Mn = Moderate, neural.
CE = Chaulmoogra ethyl esters without iodine.
CEI = Chaulmoogra ethyl esters with 0.5 per cent iodine.
CEI Cr = Chaulmoogra ethyl esters with creosote.
Mer = Heiser-Mercado mixture of chaulmoogra oil, olive oil, camphor, and resorcin.
Sodium morrhuate = Rogers's sodium morrhuate from cod-liver oil.
I = Improved.
md = Moderate.
sl = Slight.
Stat = Stationary.
+ = Traces.
++ = Positive.
+++ = Abundant.
— = Negative result of test.
? = No record.
0 = No antileprosy drugs were given.

SUMMARY AND CONCLUSIONS

1. The methods and results of the chemical analysis of blood in one hundred lepers and in seventeen presumably normal individuals are reported. The lepers were classified in the following groups: Those without complications, those with miscellaneous complications, those with tuberculosis, those with lepra reactions, and those with nephritis.

2. The blood values taken as normal for the various constituents were as follows: Nonprotein nitrogen, 23 to 33 milligrams; urea nitrogen, 7 to 19 milligrams; uric acid, 2.6 to 4.4 milligrams; preformed creatinine, 1 to 1.5 milligrams; sugar, 80 to 160 milligrams; chlorides, calculated as sodium chloride, 0.42 to 0.49 per cent. All figures were calculated as per 100 cubic centimeters of whole blood.

3. The results obtained from normal individuals are compared with those obtained by other investigational workers.

TABLE 3.—*Blood-chemistry findings in cases of leprosy without complications.*

Case No.	Duration of leprosy.	Extent of leprosy.	Antileprosy treatment.			Urine.		Non-protein nitrogen.[a]	Urea nitrogen.[a]	Uric acid.[a]	Preformed creatinine.[a]	Sugar.[a]	Chloride. (NaCl).
			Kind.	Duration.	Results.	Albumin.	Casts.						
	Years.			*Months.*									*Per cent.*
30	14					+	—	35.3	11.6		1.5	118	0.49
38	2	Sc Mn	CEI	18	I md	+	+	46.1	17.3		1.7	181	0.47
39	9	Mc Sn	CEI	18	I sl	+	—	37.5	11.8		1.7	109	0.47
42	4	Sc Mn	CEI	18	I md	+	—	46	13.1	—	1.6	95	0.46
43	3	Mc Mn	CEI	18	I sl	?	?	34	13	—	1.4	122	0.44
47	11					?	?	38	17	—	1.4	130	0.47
49	2					+	—	28	13.5	—	1.5	111	0.50
52	2					+	—	30	—	—	1.5	111	0.45
53	5	Sc Mn	CEI	18	I md	—	—	26	16.5	—	1.5	98	0.45
54	3	Mc Mn	Mer	18	Stat	+	—		19.5	—	1.5	97	0.46
58	3	Mc Mn	Mer	18	I sl	+	+	32.5	15	—	1.4	100	0.47
59	2	Sc Sn	CEI	18	I sl	+	—	27	13	—	1.5	117	0.56
60	3	Mc Mn	CEI	18	I md	?	?	25	10.9		1.5	95	0.35
63						?	?	37	13.1	4.6	1.3	103	0.48
86						?	?	25.5	10.5	4.2	1.8	100	0.49
94	10					?	?	40	12.3		1.5	125	0.44
Average								33.8	13.4	4.4	1.5	113	0.46

[a] Milligrams per 100 cubic centimeters of blood.

TABLE 4.—*Blood-chemistry findings in cases of leprosy with miscellaneous complications.*

Case No.	Duration of leprosy.	Complications.	Antileprosy treatment.	Urine.		Nonprotein nitrogen.[a]	Urea nitrogen.[a]	Uric acid.[a]	Preformed creatinine.[a]	Sugar.[a]	Chloride (NaCl).
				Albumin.	Casts.						
	Years.										*Per cent.*
13	4	Ulcers, feet	?	?	?	41.4	8.7		1.7	143	0.49
20	2	Wound, post-operation	?	+	+	27.3	11.3		1.4	181	0.49
22	13	Psychosis	?	?	?	25.5	9.9		1.3	100	0.51
31	4	Neuralgia	?	?	?	46.1	15		1.4	108	0.51
35	17	Psychosis	Chaulmoogra oil	+	—	26.6	12		1	95	0.47
70	12	Bronchitis, chronic	Mercado and CEI	+	+	30	16.5	5.6	1.4	73	0.46
72	?	Ulcers, feet	?	?	?	48	22.5	5.6	1.5	119	0.46
74	9	Anemia; uncinariasis	CEI	+	+	26.7	11.9	4	1.8	105	0.49
75	?	Ulcers, multiple	?	?	?	27	13.6	3.4	1.5	85	0.49
77	?	Arthritis	?	?	?	37	15	4.2	1.5	143	0.49
78	7	Ulcer, chronic	Mercado and CEI Cr	+	+	30	18.4	4	1.5	75	0.47
80	3	Neurasthenia	CEI	+	—	26	18	4	1.5	95	0.47
90	3	Malaria, acute	Chaulmoogra oil	+	—	27	17	4.3	1.7	95	0.46
91	14	Psychosis	Mercado and CEI	++	—	25.5	15	3	1.7	100	0.48
93	4	Dysentery	?	?	?	27	11.5	4	1.6	80	0.47
Average						31.4	14.4	4.21	1.5	106	0.48

[a] Milligrams per 100 cubic centimeters of blood.

TABLE 5.—*Blood-chemistry findings in cases of leprosy with tuberculosis.*

Case No.	Duration of leprosy.	Antileprosy treatment.	Urine.		Non-protein nitrogen.[a]	Urea nitrogen.[a]	Uric acid.[a]	Preformed creatinine.[a]	Sugar.[a]	Chloride (NaCl).
			Albumin.	Casts.						
	Years.									*Per cent.*
15	4	?	0	0	36	11.7		1.4	93	0.49
16	8	CEI and Mer			28.5			1.5	123	0.49
19	14	Sodium morrhuate	++	+	69	20		1.8	110	0.50
29	7	Chaulmoogra mixture	+	+	30	8.2		1.3	95	0.46
44	10	CEI	+	+	41.4	13.2		1.5	107	0.44
55		?			29	14		1.5	105	0.49
64	10	CEI	+	+	43.5	17.6	3.2	1.5	93	0.49
65	10	CEI and Mer	+	+	36	13.5	4.3	1.5	117	0.46
68	4	?			42	30	5.6	1.5	114	0.39
76	4	?			30	11.3	4.3	1.3	90	0.52
87	2	?	+	—	28.5	16	4.8	1.7	85	0.44
95	8	?			36	9.3		1.6	160	0.49
Average					37.6	13.3	4.64	1.5	108	0.47

[a] Milligrams per 100 cubic centimeters of blood.

TABLE 6.—*Blood-chemistry findings in cases of leprosy with lepra reaction.*

Case No.	Duration of leprosy.	Antileprosy treatment.	Urine.		Non-protein nitrogen.[a]	Urea nitrogen.[a]	Uric acid.[a]	Preformed creatinine.[a]	Sugar.[a]	Chloride (NaCl).
			Albumin.	Casts.						
	Years.									*Per cent.*
1	6	?	?	?	26.1	11	----------	1.6	107	0.48
2	6	?	?	?	46.8	15.8	----------	1.1	77	0.49
4	5	CEI	+	+	22.2	7	----------	2	107	0.48
5	10	?	?	?	45	28.5	----------	1.4	130	0.47
7	7	0	++	+	63	12.7	----------	1.8	189	0.57
10	5	CEI and Mer	+	—	49	30	----------	2	110	0.47
24	13	?	+	—	29	12.5	----------	1.2	120	0.51
27	3	CEI–Camph	+	+	37.5	9.4	----------	1.4	114	0.41
34	1	CEI	+	+	27	7	----------	1.4	77	0.47
36	5	?	?	?	30	8.6	----------	1.1	100	0.51
40	8	?	?	?	39	12.4	----------	1.5	117	0.49
45	2	?	?	?	70	36.6	----------	1.5	140	0.47
46	8	?	?	?	75	41.1	----------	1.5	133	0.48
48	5	?	?	?	40	19.3	----------	1.4	125	0.46
51	3	CEI and Mer	—	—	50	25	----------	1.4	----------	0.49
52	4	CEI	+	—	60	28.5	----------	1.5	105	0.46
67	8	?	?	?	48	18.7	4	1.4	116	0.56
71	11	?	+	+	33	21	4.8	1.4	129	0.52
73	10	?	+	—	33	15	3.6	1.3	108	0.49
82	----------	CEI	+	+	33	18.7	4	1.4	96	0.46
83	----------	CEI	+	+	30	15	4.1	1.4	94	0.51

84		?	?	?	51	25.4	4.8	1.8	154	0.54
88	16	?	?	?	36.5	13	3.2	2	100	0.47
89	8	?	?	?	33	13	4.4	1.5	95	0.49
92	16	Mer	+	—	25.5	12.7	4	1.7	120	0.52
96	5	?	?	?	34.6	12.8	4.4	1	77	0.52
Average					41	19.3	4.13	1.5	109	0.49

[a] Milligrams per 100 cubic centimeters of blood.

TABLE 7.—*Blood-chemistry findings in cases of leprosy with nephritis.*

Case No.	Duration of leprosy.	Antileprosy treament.	Urine.		Non-protein nitrogen.[a]	Urea nitrogen.[a]	Uric acid.[a]	Preformed creatinine.[a]	Sugar.[a]	Chloride (NaCl).
			Albumin.	Casts.						
	Years.									*Per cent.*
3	5	?	?	?	52	20		1.9	150	0.47
6	10	?	?	?	27.6	7.2		1.5	117.6	0.52
8	15	CEI	+	+	36	8.4		1.9	133	0.44
9	13	?	?	?	45	21.4		1.9	200	0.46
11	4	?	+	+	53.1	18		1.5	130	0.56
12	3	?	+	+	52.2	18		1.8	256	0.41
14	3	Sodium morrhuate	+	+	44.4	9.6		1.6	85	0.47
17	11	?	?	?	30	11.7		1.9	105	0.51
18	6	Mer	+	+	35	11.2		1.4	166	0.49
21	7	CEI	+	+	70.5	15		1.8	57	0.38
23	6	Sodium morrhuate	+	+	27.2	15		1.6	178	0.46
25	4	?	++	++	353	100		2.4	263	0.44
26	10	?	?	?	103	43		2.3	114	0.56
28	6	CEI and Mer	+	+	40	9.9		1.3	80	0.49
32	9	CE and CEI	+	+	33	10.1		1.2	108	0.49
33	12	Mer	+++	+	200	150		7.5	250	0.49

[a] Milligrams per 100 cubic centimeters of blood.

TABLE 7.—*Blood-chemistry findings in cases of leprosy with nephritis*—Continued.

Case No.	Duration of leprosy.	Antileprosy treament.	Urine.		Non-protein nitrogen.[a]	Urea nitrogen.[a]	Uric acid.[a]	Preformed creatinine.[a]	Sugar.[a]	Chloride (NaCl).
			Albumin.	Casts.						
	Years.									*Per cent.*
37	13	CEI	+	+	34	8.3		1.5	166	0.57
41	4	CEI	+	—	30	8.5		1.6	89	0.49
50	5	CEI	++	—	45	21.9		1.4	133	0.49
57	4	?	?	?	30	15		1.3	121	0.47
61	11	CEI	+	+	109	36.1		1.5	174	0.37
62	4	CEI	+	++	39	15	2.3	1.3	114	
66		CEI	+	+	27	17.2	3.2	1.4	166	0.42
69	2	CEI	+	+	42	22	4.8	1.3	105	0.49
79	6	CEI	+	—	34	23	4	1.5	80	0.49
81	3	CEI	+	+	26	12.7	4.6	1.9	90	0.49
85		CEI	+	+	46.4	21.6	4.2	1.8	160	0.54
97	4	?	?	?	62	46		1.3	111	0.49
98	3	?	?	?	55	17		1.7	117	0.51
99	8	?	?	?	60	19		2.5	166	0.49
100	5	CEI	+	—	57.7	18		1.1	75	0.41
Average					45.4	24.8	3.85	1.8	137.4	0.46

[a] Milligrams per 100 cubic centimeters of blood.

TABLE 8.—*Blood-chemistry findings; group averages.*

Table.	Condition of cases.	Nonprotein nitrogen.[a]	Urea nitrogen.[a]	Uric acid.[a]	Preformed creatinine.[a]	Sugar.[a]	Chloride
							Per cent.
1	Normal nonlepers	28.3	14.3	3.5	1.2	96.7	0.46
3	Lepers without complications	33.8	13.4	4.4	1.5	113	0.46
4	Lepers with various complications	31.4	14.4	4.21	1.5	106	0.48
5	Lepers with tuberculosis	37.6	13.3	4.64	1.5	108	0.47
6	Lepers with lepra reaction	41.06	19.3	4.13	1.5	109	0.49
7	Lepers with nephritis	45.4	24.8	3.85	1.8	137.4	0.46

[a] Milligrams per 100 cubic centimeters of blood.

4. A study of the results collected brings out the following facts:

(*a*) No regular correspondence can be traced between the blood findings and the duration, extent, or type of leprosy, or the antileprosy treatment.

(*b*) The average values for nonprotein nitrogen, uric acid, creatinine, and sugar for all of the leper groups were somewhat high, although many individual cases showed normal values.

(*c*) The average values for nonprotein nitrogen and urea nitrogen are markedly high, not only in the group of lepers with nephritis, but also in the group with lepra reactions.

(*d*) The group averages for urea nitrogen are normal except as above stated, and those for chloride are normal throughout.

ACKNOWLEDGMENTS

I wish to express my appreciation to Dr. Granville A. Perkins, chief chemist, Culion Leper Colony, for his valuable advice and suggestions in connection with the preparation of this paper; and to Dr. Froilan Eubanas, of the medical section, for his kind coöperation, including the furnishing of most of the blood specimens.

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COLLEMBOLA FROM THE PHILIPPINES AND NEW CALEDONIA

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TWO PLATES

In June, 1924, a small collection of Collembola was sent to me by C. F. Baker of Los Baños in the Philippine Islands. They were collected on Mount Maquiling, in central Luzon.

The little apterous insects reported herein are the first forms of their group to be recorded for the Philippines. For that reason they are important, not only for zoögeographic investigation but also for systematic.

This collection furnished the following four species, two of them new to science:

Ceratimeria pulchella sp. nov.
Achorutes bakeri sp. nov.
Lepidocyrtus parvidentatus Schaffer.
Pseudoparonella setigera C. Börner.

A *Lepidocyrtus* and an *Aphysa* were represented by young individuals which could not be identified.

At the same time I add two forms, collected by Dr. F. Sarasin and Dr. J. Roux in New Caledonia, of which one especially is of the highest importance as representative of a new genus. The two forms are—

Hypogastrura longispina Tullb.
Chaetoceras sarasini g. et sp. nov.

Ceratimeria pulchella sp. nov. Plate 1, figs. 1 to 6.

Length, 2.5 millimeters. Body color above dark purple, marked with nine large white spots; two are on the lateral and posterior parts of the head, two lateral on the median parts of Th. II and Abd. II, two on the sides of Abd. IV, and a median one on Abd. V. The conus of the mouth parts, the fourth joint of the antennæ, the legs, and all sternal parts of the body beneath are entirely ivory white. On the legs only a small triangular spot at the base of the subcoxæ remains purple. The antennæ are four-jointed and lie underneath the head at the side of the conus of the mouth parts. Fourth joint of antennæ with

simple bristles; third with apical antennal organ, composed of a pair of curved papillæ and two short guard setæ. Eyes 8 + 8. Postantennal organ composed of 27 tubercles in a deep groove; several of the tubercles in a middle row, as has been observed in *Ceratimeria longicornis* E. H. from Java. The unguis is simple, without teeth either on the inner or on the outer margin. Unguiculus absent. No tenant hair on the tibiotarsus. Furcula well developed. Mucrones a third as long as the dentes. The granulation of the skin of the latter continues on to the inner lamella of the mucro. Mucro simple, not hooked apically, subtriangular in form.

Ceratimeria pulchella is closely allied to *Ceratimeria maxima* Schott from New Guinea and the Sunda Archipelago and *Ceratimeria longicornis* from Java. It differs from both in the general shape, the color, and the structure of unguis and mucro.

The single specimen of this striking, well-defined species is preserved in my collection.

LUZON, Mount Maquiling (*Baker*).

Achorutes bakeri sp. nov. Plate 1, figs. 7 and 8.

Length, 2 to 3 millimeters. Color entirely white. Body with segmental humps, especially pronounced on the sides and dorsolaterally; each with long, stiff, naked bristles; all setæ without special structure. Antennæ short, four-jointed, fourth joint with somewhat excentric, retractile, subapical papilla and six to seven olfactory setæ on the outer side; the sense organ on third joint of normal structure, as in other species of the genus. Mouth parts for sucking. Three unpigmented eyes on each side, two close together just before the outer bristle hump, which bears the third eye on its back. A sort of postantennal organ before the first two eyes, the surface of which shows a fine granulation of the epidermis. Skin grossly tuberculated. Tubercles on the humps arranged in lines, running toward the apical bristles. Claw without teeth, but basally with a fine toothlike lamella. Unguiculus and tenant hairs absent.

Achorutes bakeri differs from other oriental species of the genus by the number of ommatids in the eye, the presence of the postantennal organ, the naked bristles, and the toothless unguis. The collection contains about ten specimens.

The species is named for C. F. Baker, to whose kindness I owe the material, and who collected it on Mount Maquiling, Luzon.

Lepidocyrtus parvidentatus Schaffer. Plate 2, figs. 9 and 10.

Lepidocyrtus parvidentatus was discovered by Schaffer in 1898. As it is necessary to have complete diagnoses illustrated with figures for the identification of the very difficult species of *Lepidocyrtus*, I here add drawings and a new description of the Philippine form, which I believe may be identified with the old species, *parvidentatus*.

Color brownish, scales somewhat darker. Violet pigmentation between the antennæ on the head and also on the antennæ. The body, especially the sides of Abd. II and IV, and the dorsal and ventral sides of Abd. IV violet. The proximal part of Abd. IV with a series of longitudinal violet stripes. The femora of all legs dark violet, except on the first leg, where only the coxæ are dark colored. The scales are rounded on both sides. The hair covering is especially dense on the legs, the antennæ, and the furca. Proportions: Ant. I:II:III:IV=5:12:12:20; Head: 42; Abd. III:IV=10:75; legs (tibiotarsi) I:II:III=20:28:40. (One specimen shows in Abd. III:IV only 7:43). Upper claw slender, with two inner teeth; lower claw long, without tooth, inner margin not truncated or cut off squarely. Tenant hair long. Mucro with long apical hook. Inner hook small and basal spine hardly visible.

LUZON, Mount Maquiling (*Baker*).

Pseudoparonella setigera C. Börner.

This form has also been recorded from the Malay Archipelago. Börner described it from Tjibodas in Java, and in material belonging to the Buitenzorg Museum it was present from the Lampong District in Sumatra. It seems, therefore, that the species has a wide geographical dissemination through all the islands of the East Indian Malayan seas.

LUZON, Mount Maquiling (*Baker*).

The specimens from Sumatra and the Philippines show no morphological differentiation.

Among the material collected by Dr. F. Sarasin and Dr. J. Roux in New Caledonia in 1910 are two vials containing specimens of Collembola, representing two species. One of these is the well-known cosmopolitan form *Hypogastrura longispina* Tullb.

According to the communication of Doctor Roux, the form occurred in huge masses upon the surface of small pools in the

forest. No difference can be observed between the individuals of New Caledonia and those of Europe.

The other form represents a genus of the Paronellini, not known until this time.

Genus CHAETOCERAS novum

Body long, slender. Antennæ more than twice as long as the body, underneath with long stiff bristles, sometimes of the length of a joint. Furca broad, nearly as long as the body. Mucro smooth, not disarticulated from the dentes, with coarse teeth. Body covered with broad, dense, serrated bristles.

The genus seems to connect Paronellini with Cremastocephalini. The nearest form may be Schott's *Paronella queenslandica;* but there are still wide differences in the hooks of the mucros, the form of the bristles, and the specific antennal setæ. The latter, especially, I have never observed in any other genus of the whole group.

Chaetoceras sarasini sp. nov. Plate 2, figs. 11 to 14.

Length, 2 to 3 millimeters. Body long, slender, color yellowish, with pink stripes on the dorsum of Abd. IV. Eyes on black spots, 8 on each side. Antennæ more than twice as long as the body (170:348) Ant. I:II:III:IV=60:78:50:170. The first three joints underneath with long, stiff bristles, often longer than a joint. Antennal joints III and IV finely annulated. Antennal organs were not observed. Mouth parts for chewing. Body segments: TH. II:III; Abd. I:II:III:IV:V:VI=25:20:8:10:8:85:9:4. Legs with bristles even as long as those on the antennæ. Ti. I:II:III=51:55:69. Claw with two inner teeth and a large outer one. Inner claw simple, the inner edge without tooth. Tenant hair as long as the claw. Furca long. Ma.: DeMu.=63:70. Dentes basally and apically of the same size. Mucro not disarticulated from the dentes, coarse, with two teeth. Body covered with broad, dense, somewhat scalelike, plumose bristles. Long stiff bristles always smooth.

Habitat, Ngoi Valley, New Caledonia (*Sarasin*).

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ILLUSTRATIONS

Plate 1

Fig. 1. *Ceratimeria pulchella* sp. nov., dorsal aspect.
2. *Ceratimeria pulchella* sp. nov., ventral aspect.
3. *Ceratimeria pulchella* sp. nov., sense organ of third segment of the antenna.
4. *Ceratimeria pulchella* sp. nov., postantennal organ of the left side.
5. *Ceratimeria pulchella* sp. nov., foot.
6. *Ceratimeria pulchella* sp. nov., dentes and mucro.
7. *Achorutes bakeri* sp. nov., eyes and tubercle of the skin.
8. *Achorutes bakeri* sp. nov., foot.

Plate 2

Fig. 9. *Lepidocyrtus parvidentatus* Schaffer, foot.
10. *Lepidocyrtus parvidentatus* Schaffer, end of the dentes with mucro.
11. *Chaetoceras sarasini* g. et sp. nov., right aspect.
12. *Chaetoceras sarasini* g. et sp. nov., setæ on the antennæ.
13. *Chaetoceras sarasini* g. et sp. nov., foot.
14. *Chaetoceras sarasini* g. et sp. nov., end of the dentes and mucro.

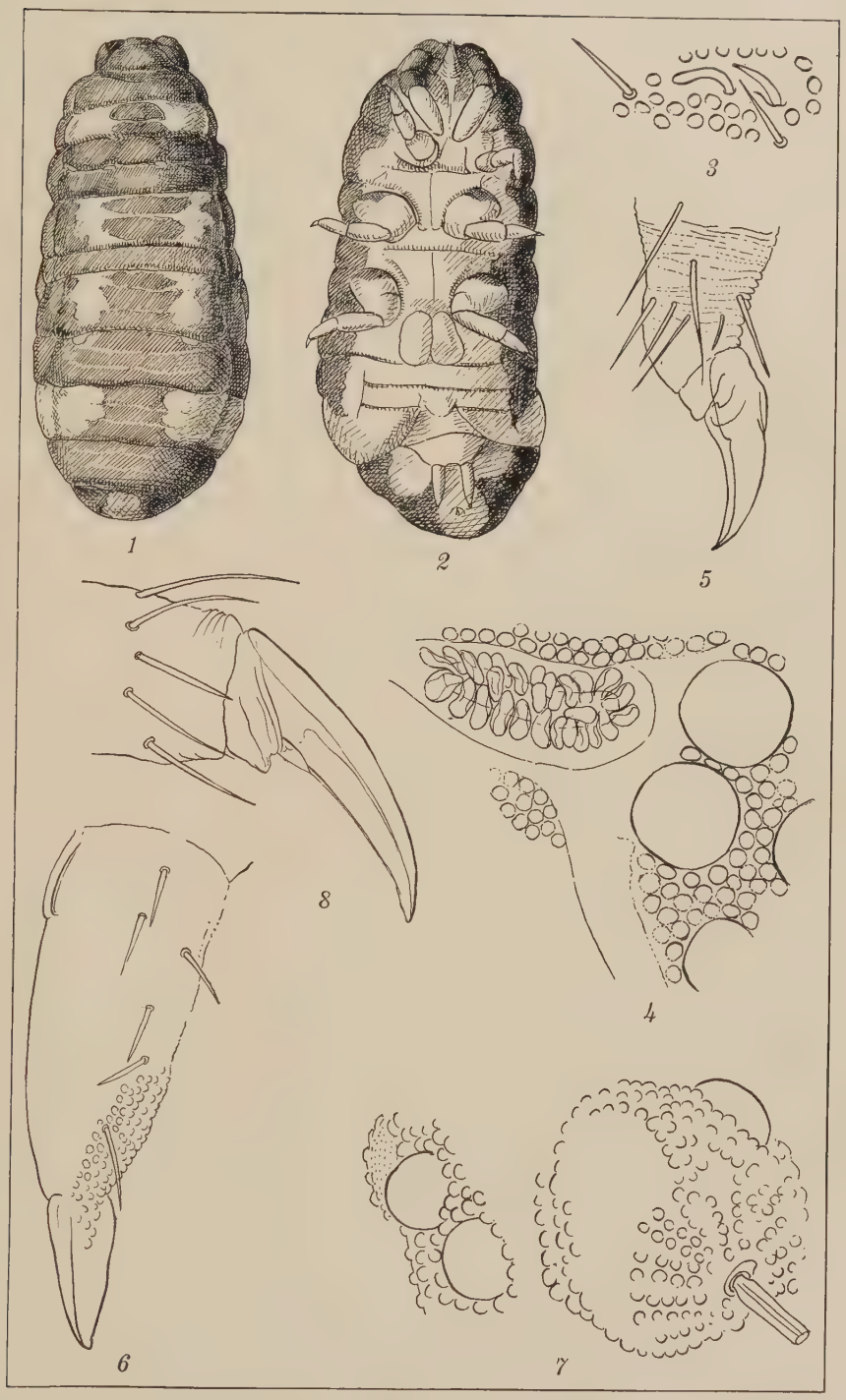

PLATE 1.

PLATE 2.

DIOCALANDRA TAITENSIS (GUERIN) AND OTHER COCONUT PESTS OF FANNING AND WASHINGTON ISLANDS

By WILLIAM B. HERMS

Professor of Parasitology, University of California, Berkeley

EIGHT PLATES AND THREE TEXT FIGURES

The investigation of which this paper constitutes a report is the result of a request to the College of Agriculture of the University of California from the London owners of Fanning and Washington Islands through their San Francisco agent for assistance in the identification and control of certain coconut pests prevalent on those islands. In order to undertake this work I was granted a four-months leave of absence, and on April 10, 1924, sailed from San Francisco on the company's motor schooner *Doris Crane,* arriving at Fanning Island May 3, after a voyage of twenty-three days. It is a matter of great satisfaction to be able to tender my hearty thanks to the representatives of the company (Fanning Island, Ltd.), both in connection with the voyage and during the progress of the work on the islands, for the kind treatment received. Thanks are particularly due to Mr. D. B. Crane who arranged the San Francisco details; Capt. John McCulloch of the *Doris Crane;* Maj. C. Burn-Callander, manager of Fanning and Washington Islands, who at all times accorded me the heartiest coöperation; and to my volunteer assistant, Mr. Harold Kirby, jr., graduate student in zoölogy, who accompanied me throughout the trip. Although I left Fanning Island for San Francisco via Honolulu on July 27, certain observations were nevertheless continued by Mr. Kirby until his departure, October 3.

Fanning and Washington Islands belong to a group of equatorial islands of the Pacific Ocean lying in a northwesterly-southeasterly position about midway between the Hawaiian and the Society Islands. The four main islands of this group are Christmas, nearest the equator (1° 57′ north latitude and 157°

27′ west longitude);[1] Fanning, about 145 miles northwest (3° 54′ 38″ north latitude and 159° 23′ 27″ west longitude); Washington, located 66 miles northwest of Fanning; and Palmyra, 126 miles northwest of Washington. Fanning is the most important of these islands, primarily because it is the seat of a British cable station, and also because it is a source of considerable quantities of a superior grade of copra. Other than through cable connection, Fanning Island is reached at intervals of about two months by steamers of the Union Steamship Company plying between Auckland, New Zealand, and Vancouver, British Columbia, and by the Fanning Island, Ltd., motor schooner *Doris Crane*, which sails at irregular intervals between San Francisco and Fanning and Washington Islands, and on recruiting trips to the Gilberts and South Sea Islands.

Fanning Island (fig. 1) is a typical coral atoll, consisting of a narrow rim of land hardly three-fourths of a mile in width

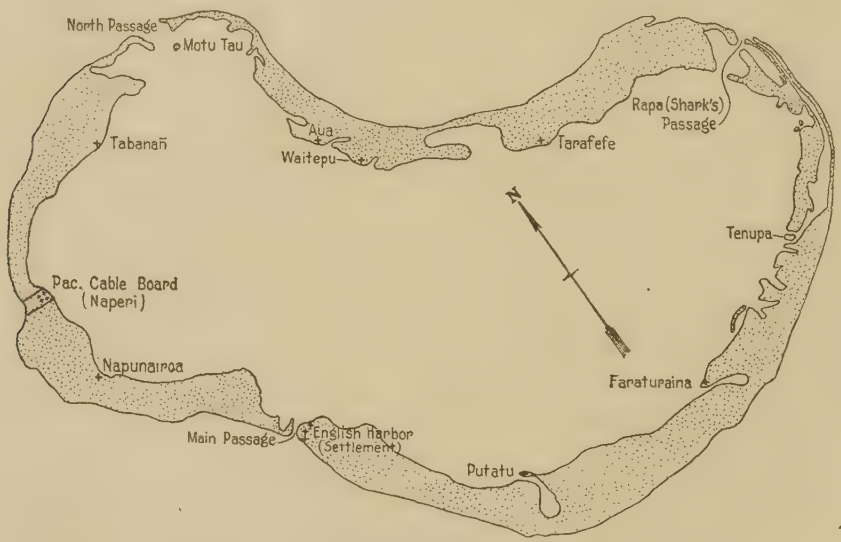

FIG. 1. Fanning Island, Pacific Ocean.

at the most and inclosing a lagoon. The island is approximately 10.5 miles long and 5.5 miles wide, with an external circumference of 31 miles. The rim of land at the outer edge, consisting of coral bowlders and shingle, is thrown up somewhat like a wall and is about 10 feet above mean tide level; the rest of

[1] Edmonson, Charles Howard. Crustacea from Palmyra and Fanning Islands. Bernice P. Bishop Museum Bull. 5 (1923) 1–43, pl. 1, 2.

the land is only 2 to 6 feet above mean tide level. For perhaps 200 feet inland from the sea the shore is strewn with coral bowlders and shingle of irregular shapes and sizes, often very jagged. There are three passages into the lagoon; namely, the Main Passage on the east side, with a minimum width of 850 feet, and navigable; Rapa, or Shark, Passage on the east side, with a minimum width of 525 feet; and North Passage on the north side, with a minimum width of 2,000 feet. Neither Rapa nor North Passage is navigable and with the Main Passage roughly divide Fanning into three smaller islands.

The total area of Fanning Island comprises about 8,500 acres, of which over 3,200 acres are in coco palms, approximately one-third of which are wild trees. In order properly to care for the harvesting of nuts, labor camps are located at intervals on the island. These camps are located as follows, and this information will assist in making comparisons later on in this report; namely, English Harbour (the Settlement), Company Headquarters, located at the Main Passage (south side) on the west side of the island with a labor camp near by; Fareturaina, located at the south-southeast end; Tenupa, at the southeast end; Tarafefe, at the northeast side with Shark Passage, or Rapa, between it and Tenupa; Aua, on the north side, separated from Tabonañ at the northwest end by North Passage; Naperi, the Pacific Cable Board; Napunaiaroa, situated on the west side about halfway between the Cable Station and the Main Passage.

During the course of this investigation the various points were reached mainly, first by launch and then on foot, through the bush adjacent to the several camps. The Napunaiaroa division was easily reached either from the Cable Station (by launch) or from the Main Passage after crossing by launch, while the Fareturaina and Tenupa divisions were reached on foot or for part of the distance by means of a Ford truck. Aua and Tarafefe were always made by launch, while Tabonañ was reached either by launch or via the Cable Station. A part at least of practically every day during the length of our stay was spent in the bush among the coco trees, and often the entire day was used in the pursuit of field observations. Through the thoughtfulness of the manager, Major Burn-Callander, we were given ample laboratory space at English Harbour, where breeding experiments and other laboratory observations were conducted and where the adequate supply of instruments, such as microscopes, thermograph, hygrograph, and

other equipment supplied by the University of California, could be used to good advantage.

The opportunity for the study of the Washington Island situation was too limited to carry on a detailed investigation. This island was visited May 13 to 16 inclusive (less than four days), the trip from Fanning having been made by the *Doris Crane* during the night of May 12. Owing to an unhappy landing in a small surf boat during a heavy sea, I sustained a painful injury which, together with other handicaps, made a study of the island rather difficult; however, through the ever thoughtful assistance of Major Burn-Callander, much was accomplished nevertheless. At the time of our visit the island had not been inhabited for about four months, and then only for a very brief period; hence the plantation did not present a very good condition. The island had really not been under care for about one and a half years, according to the manager.

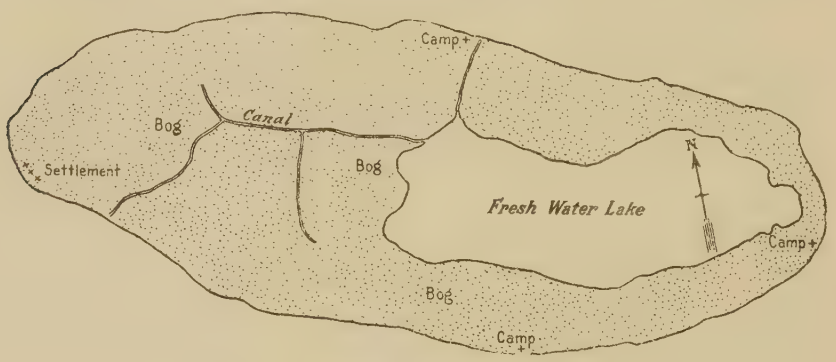

FIG. 2. Washington Island, Pacific Ocean.

Washington Island (fig. 2) is about 4.5 miles long and 1.5 miles wide, with an external circumference of about 10 miles. The central area of the island toward the south end consists of a fresh-water lake about 2 miles long and averaging about half a mile in width. The highest elevation is slightly over 10 feet above mean tide level. The ocean beach is largely sand, thus contrasting markedly with the rather uniformly rough ocean beach of Fanning. The island is traversed by two main canals for drainage purposes as well as for the transport of nuts. There are close to 2,100 acres in coco palms which are practically all wild (not over 200 acres planted), often growing in almost impenetrable thickets of tropical vegetation. Owing largely to lack of cultivation and a greater annual rainfall than at Fan-

ning, thus giving opportunity and impetus for rank growth, Washington Island (Plate 1, fig. 1) gives one the impression that it is much more tropical than is Fanning. The fauna and the flora of the two islands are, however, with few exceptions, very similar.

CLIMATIC DATA

Very few accurate data covering a period of time long enough to estimate fair averages for Fanning Island are available at the office of the company, and practically none at all for Washington. The total rainfall for Fanning during 1918 (to December 20, inclusive) was 102.76 inches, for 1922 it was 59.32 inches, and for 1923 it was 66.41 inches, while for the first eight months of 1924 it was 55.38 inches. The two years for which there is a complete record, namely, 1922 and 1923, are said to have been rather dry years. It is quite probable that the average total annual rainfall of Fanning is between 75 and 80 inches. It is obvious, from general observation and incomplete data, that the average annual rainfall for Washington Island is much greater than that for Fanning. While the months of December to May are said to have a heavier rainfall, the records for Fanning show that the precipitation for July, 1923, was 14.88 inches, the highest recorded for either 1923 or 1922, and January, February, and March of 1923 show 0.32, 0.35, and 0.55 inches. Table 1 shows the precipitation by months, as recorded in the office of the company.

TABLE 1.—*Showing rainfall in inches for Fanning Island by months for the years 1918, 1922, 1923, and 1924 (in part).*

Month.	1918	1922	1923	1924
January	0.72	2.17	0.32	14.17
February	1.71	7.07	0.35	9.16
March	2.63	5.58	0.55	7.90
April	4.38	11.22	5.49	11.01
May	7.23	13.47	8.90	3.27
June	19.70	9.50	6.15	2.52
July	15.36	4.06	14.88	2.98
August	10.60	.56	4.86	4.37
September	10.92	1.25	5.94	----
October	10.06	.12	4.73	----
November	4.41	.71	4.89	----
December	[a] 15.04	3.61	9.35	----
Total	102.76	59.32	66.41	----

[a] To December 20, inclusive.

The temperature for Fanning Island, due to trade winds and ocean influence, is remarkably equable, and the daily temperature curve usually shows a striking similarity from day to day (fig. 3). With the thermograph placed at a south window opening of the laboratory and fully protected by a close-fitting canvas curtain over the opening, the temperature during the time of our stay (May to July, inclusive) stood at about 80° F. from about 7 o'clock at night to about 7 o'clock in the morning with a slight downward variation of a degree or two, when it began to rise, approaching 85° F. at about 9 o'clock and remaining near this point with slight deviation until about 4 o'clock in the afternoon when it began to decline (see fig. 3). Deviation from this general daily performance is illustrated by a consecutive twenty-four-hour period when the curve ranged between 76 and 79° F., during which time there was almost continuous rain and high humidity. The office records show a rare maximum temperature of 93° F. and a minimum, equally rare, of 70° F. The annual mean temperature is slightly in excess of 81° F.

The temperature as recorded at Washington Island (no thermograph used) during the very few days of our stay showed little difference from that at Fanning. Nevertheless, the bush, away from the immediate ocean breeze, presents a tropical and humid atmosphere, due to the density of the tall vegetation which is given impetus by the great amount of moisture in the soil, considerable areas of which are veritable bogs difficult to traverse. The actual temperature at Washington at 5.50 p. m. on May 13, 1924, was 78° F.; at 8.30 a. m., May 14, it was 80.5°; at 7.30 a. m., May 15, it was 79°; and at 7.30 a. m., May 16, it was 80°. The thermograph record for Fanning Island at the same time shows almost identical temperatures except for May 13, when it was cooler at Washington, owing no doubt to the rainy weather at the time.

The maximum and minimum temperatures as recorded for Fanning Island in the company's office are shown in Table 2. For this table I used only the monthly maximum and minimum for the purpose of this paper.

The relative humidity of Fanning as measured by the sling psychrometer ranged from 72 to 76, inclusive, during the months of May to July, inclusive. The range for Washington during our brief stay there was 71 to 77, inclusive.

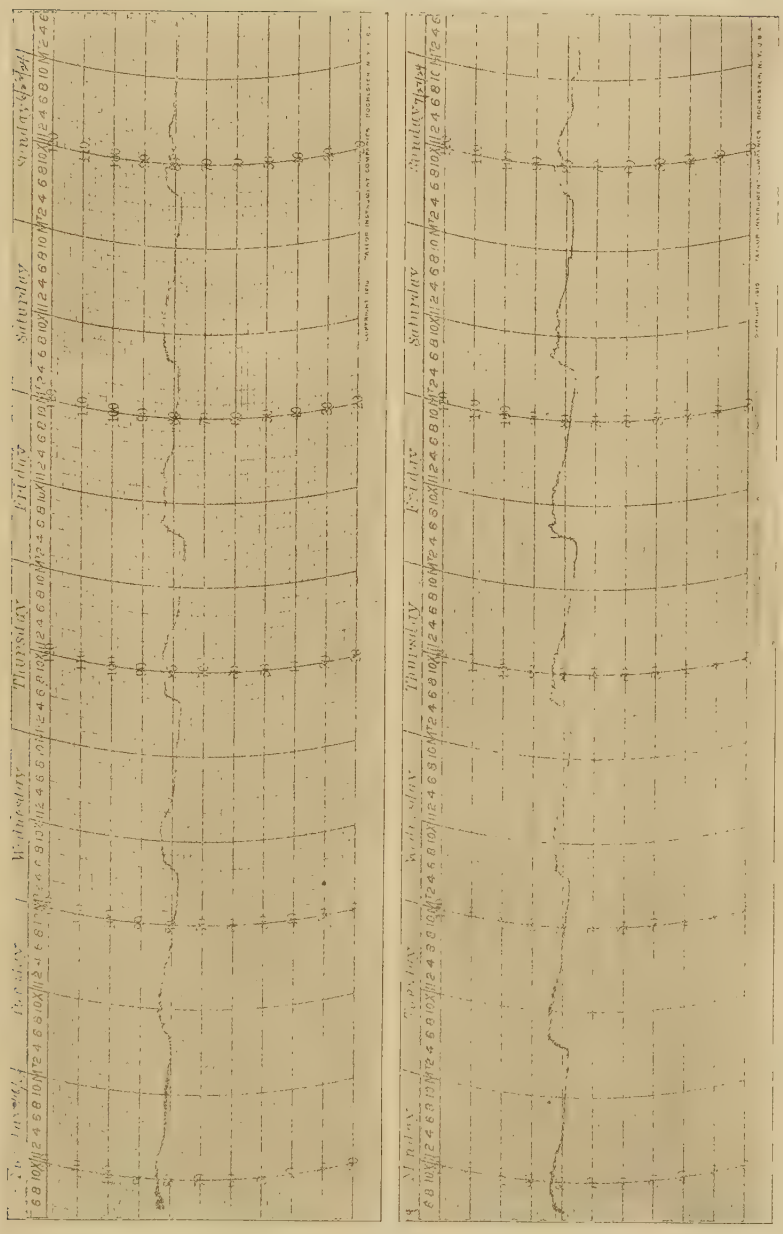

FIG. 3. Thermograph records from Fanning Island for two weeks, showing remarkable daily uniformity.

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TABLE 2.—*Showing monthly maximum and minimum temperatures in degrees Fahrenheit, for Fanning Island, as recorded in the office of the company.*

Month.	1918		1922		1923		1924	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
January	89	72	87	74	84	73	90	72
February	89	72	86	72	85	75	86	71
March	89	72	86	74	86	75	88	70
April	91	74	85	74	86	74	90	70
May	91	73	86	73	88	74	90	70
June	91	73	86	74	90	73	90	70
July	91	73	85	74	89	74	-------	-------
August	93	73	85	72	86	74	90	70
September	90	73	88	75	86	75	-------	-------
October	90	73	88	74	89	76	-------	-------
November	93	73	86	73	86	74	-------	-------
December	93	74	83	74	84	74	-------	-------

VEGETATION IN GENERAL

Coco palms constitute the dominant vegetation on both Fanning and Washington Islands. While the flora of Fanning Island is typically tropical in nature, it is not so dense as one might expect, though in many places the "bush" is almost impenetrable. These thickets, mainly skirting the ocean shore, consist largely of umbrella, or tahuna (*Tournefortia argentea* Linn. f.), which farther inland often reaches the proportions of fine trees, 40 to 50 feet in height. Nashu (*Scaevola frutescens* Krause) is a densely growing shrub forming part of the thicket, reaching a height of 10 to 15 feet; it is vinelike and difficult to penetrate. Buka (*Pisonia grandis* R. Br.), also much in evidence as a part of the bush, is known as "the wood that grows," since posts made of this wood when placed in the ground soon grow abundant, bright green foliage. Pandanus, or screw pine (*Pandanus* sp.), grows abundantly on Washington Island and less so on Fanning. The strong, often tall and symmetrical trunks are used for rough construction purposes, native huts, etc. The papaya (*Carica papaya* Linn.) is fairly abundant on both islands, particularly Fanning, and bears profusely. Bananas are also fairly abundant and do very well. Near the Main Passage on Fanning there are several splendid breadfruit trees, limes, and mangoes. Ferns (*Polypodium scolopendrium* Burm. f. and *Asplenium nidus* Linn.) and an aroid (*Cyrtosperma chamissonis* Merr.) grow to immense size on Washington and form a prom-

inent part of the vegetation there, but are either absent or inconspicuous on Fanning. A more-detailed account of the flora of these two islands will be published at a later date.

GENERAL CONDITION OF PLANTATION ON FANNING ISLAND

A visit to the various camps on the island and a general view of the neighboring bush give one a fairly favorable impression so far as the general health of the trees is concerned, although there is evidence of neglect in past years, notably in the territory from 1.5 to 3 miles southerly from the Settlement where the trees have been badly handicapped. Here great quantities of brush have recently been cut from between the trees and are now lying piled in great, long heaps, to be burned later. The difference between the growth of trees planted in areas fully cleared and that of trees in only partly cleared areas which have in time become badly choked up is shown in Plate 2, fig. 1; many of the trees shown, at the age of 8 to 9 years, are far behind those of 2.5 to 4 years, shown in Plate 2, fig. 2.

Collections of rubbish (old fronds, husks, brush, etc.) such as one sees in many parts of the island produce very favorable breeding places for rats, which are abundant on the island and, if such pests as the rhinoceros beetle (for example, *Oryctes rhinoceros* Linn.) and other species which breed in rubbish, should unfortunately be introduced, most convenient harborage and protection would at once be available. Furthermore, such collections of rubbish easily conceal intruders until, perhaps, they have become permanently established.

Not only does this rubbish lie for months as a menace, and apparently much of it has already lain for years, but the final disposal of it by burning (which has been done in some places) presents another problem of some importance; namely, many of the young trees become charred in the process and consequently suffer retardation. To drag this enormous quantity of brush to a location free from coco palms, there to be burned, would entail prohibitive expense; hence it must either lie and rot or be burned in situ. To let it lie would prevent necessary sanitation and retard future nutting; hence the other alternative, burning, has already been pursued, in spite of the fact that some retardation must result and some young trees will be lost. Plate 2, fig. 3, illustrates the result of indiscreet burning. If care is exercised (see Plate 3, fig. 1), the damage caused to young trees by fire can be reduced to a minimum. The recovery of certain endogenous plants, particularly the coco palm,

from severe fire injury is very remarkable, and burning of this rubbish can be readily accomplished if judgment is exercised as to wind. Obviously, the proper procedure is to clear the land thoroughly before planting, thus eliminating the problem just described, provided general sanitation of the plantation is continuously practiced thereafter. This will certainly be less expensive in the long run and the good results from healthy trees, unrestricted by choking brush and later by charring flames, emphasizes the correctness of this procedure, not to mention the elimination of nesting places and harborage for certain pests. It would appear practical to leave spaces here and there at certain intervals where rubbish can be carried and burned from time to time without menacing the trees.

A rapid, superficial inspection of many hundreds of trees, covering more than 3,000 acres, would naturally bring one into contact with a number of diseased and dead trees, due to various causes (soil conditions, injury, pests, etc.), for certainly it would be rather remarkable if every planted or wild tree should have survived the ordinary vicissitudes of existence over a period of years. Thus, the total annual morbidity and mortality of a very large city in actual numbers appears to be very great when compared with those of a small town, but when reduced to a percentage basis the situation is not alarming. I do not believe that the percentage of dead and dying trees on Fanning Island would be at all alarming, but when a very careful inspection of each tree in a given area is made and a high percentage of infection is found, then thought should be given to the future, not only to forestall if possible an unduly high death rate, but more particularly to prevent a reduction in the quantity and quality of the fruit.

Shortly after our arrival a careful inspection was made of many individual trees in certain areas on Fanning Island. In one of these areas between 1.5 and 2 miles southerly from the settlement, two hundred seventeen young trees, approximately 2 to 10 years of age, were examined; one hundred thirty-nine, or 64 per cent, of these showed in some degree the work of *Diocalandra taitensis* (Guerin); eight trees, or 4 per cent, were in a dying condition, due to a combination of beetle and caterpillar attack. Of the total number of trees examined forty-eight were rather too young to show the effect of *Diocalandra*, for it appears that this insect does not readily attack the trees until they are somewhere near 3 to 4 years of age; hence, if these young trees are not counted in the total (217), the percentage

of infection among the susceptible trees would be very high, namely, 82 per cent. This percentage of infection corresponds very well with the estimated amount of infection in certain areas between the Cable Station and Napunaiaroa. This high rate of *Diocalandra* infection is not necessarily cause for great alarm, since the damage in many cases is rather neglible, as will be explained later.

While the heaviest beetle infestations are to be found between the Cable Station and Napunaiaroa and near English Harbour (from the Main Passage southerly for about 3 miles), in both of which localities the "white" scale (see later pages) is also rather abundant, the least infestation is noticeable in the neighborhoods of Aua and Tarafefe, particularly Aua. At Tarafefe there is more or less infestation of the younger planted trees in the immediate vicinity of the camp. Toward Rapa Passage southerly from Tarafefe the trees are practically all wild and fairly old. There is, however, not a little of the white scale present in this area. Fareturaina has a slightly heavier infestation near the camp, but in general the young trees in that vicinity are in very good condition. The Tabonañ district is separated from the Cable Station by an extensive thicket nearly 2 miles in length consisting of umbrella, *Pandanus*, and buka. In the immediate vicinity of Tabonañ camp the infestation of *Diocalandra* is rather markedly a trunk infestation, though other parts of the trees are infested, as in other localities. In general, this district shows much less infestation than either near Napunaiaroa or English Harbour and more than either Fareturaina, Tarafefe, or Aua. Notwithstanding the fact that this area contains many more trees at the age when this infection should show most if present, the general thrifty condition of the trees is evident. A few dead or unthrifty young trees show evidence of severe caterpillar (see later pages) infestation, and several older trees appear to have had the tops badly charred, possibly by lightning. Rats are certainly abundant in this area and are responsible for some damage to the spikes and young coconuts.

PESTS IN GENERAL

Rats (*Epimys alexandrinus*).—Rats are to be found practically everywhere on the plantation, and they present a problem which deserves careful attention. The very considerable quantity of rubbish in most parts of the island affords excellent breeding places, as evidenced by nests with young rats in old coco

stumps, fallen and decaying trees, etc. The tops of many trees are literally inhabited by rats, due very largely to the accumulation of dead fronds, inflorescences, etc., which provide good nesting material and a safe harborage. The damage done by rats is partly shown in Plate 3, fig. 2, and many young nuts on the trees show similar treatment. Furthermore, these pestiferous creatures have also the habit of gnawing at the bases of the individual spikelets, causing young nuts to die and fall or, when done very early, causing the female flower to drop off. Frequently every spikelet on a flower stalk shows such rat gnawings, and complete barrenness results. The difference in quantity of fruit produced when a tree is treated for rats was well shown in several old trees at Aua, which prior to this treatment were said to be quite barren. The tops of these trees had been cleaned out, fronds interlacing with fronds of other untreated trees were cleared, low hanging fronds were trimmed or removed, and a tin band (gasoline tin) was placed near the base of each tree, with the result that when we saw these trees they were well laden with fine nuts. Rats on the island could certainly be considerably reduced, and I believe with profit, by a combination of methods judiciously applied; namely, ratproofing as above described, in certain cases only; sanitation, removal of débris by burning; and rat poisoning, by the use of barium carbonate, one part to eight parts of oatmeal mixed with water into a stiff dough and placed in rat runways.

Coconut crabs (*Birgus latro* Herbst).—Coconut crabs (Plate 8), while still to be found on Washington Island, are almost extinct on Fanning Island; hence, they are not a factor in pest-control operations.

Scale insects.—Scale insects are represented principally by *Hemichionaspis aspidistrae* Signoret (Plate 1, fig. 2), which occurs in all parts of Fanning Island and is abundant in places, notably between the Cable Station and Napunaiaroa. This scale attacks all parts (except roots) of both young and old trees. Ripe nuts in husk in certain badly infested trees are sometimes almost white due to the presence of countless numbers of the white male scales. Although at present it is neither abundant enough nor sufficiently damaging to require the specific employment of control measures, this scale insect should nevertheless be kept under surveillance. Many of the scales, both male and female, are parasitized by *Aspidiotiphagus citrinus* (Craw.) but not abundantly as suggested for this scale in other places

by Doane;[2] however, it is quite probable that the parasite will increase rather than decrease and it is likely that it will hold the scale in check. The scale occurs also on several species of weeds and shrubs, in agreement with Doane's observations elsewhere.

Mealy bugs.—Mealy bugs (probably *Pseudococcus pandani* Ckll., which occurs on coconuts in many of the South Sea islands) are fairly widely distributed, though not abundant enough to cause any anxiety at this time. It is true, however, that this species is nevertheless responsible for considerable damage in other localities.

Caterpillars.—Damage by caterpillars was observed in many parts of the island, and very young trees are rapidly killed when these insects feed on the tender young cabbage. Should many young nursery trees be set out, these insects would, no doubt, prove a source of some worry, since they are well concealed within the folds of the young leaflets, and cannot be reached with ordinary spray materials. The younger leaflets soon turn yellow and die, the older leaflets become crinkled, and the entire frond finally presents a much-contorted appearance (Plate 5, fig. 1). The young trees thus infected are usually badly twisted and present a very ragged, almost charred appearance. Not only are the larvæ well concealed within the folds of the leaflets (underside), but also they spin a very delicate, protective web, within which, when disturbed, the larva retreats with remarkable speed. The full-grown larvæ measure about one inch in length and spin rather tight-spun white cocoons. I do not know how long the larva requires to reach full growth, but the pupal period requires but six or seven days. The newly emerged moth is of a very beautiful shining lemon color. The species remains unidentified.

Coconut beetles.—Beetles belonging to two species [*Sessinia (Anaca) collaris* (Sharp), dark in color, and *Sessinia (Anaca) decolor* (Fabricius), light brown] each about a half inch in length, in about equal numbers, are generally distributed over the island and fairly swarm over the male flowers of newly expanded inflorescences. The beetles thrust their heads eagerly into the flowers and feed upon the pollen. Newly opened inflorescences generally present a very lively picture with literally dozens of these beetles most eagerly at work, and several small

[2] Journ. Econ. Ent. 2 (1919) 220–223.

lizards of two species licking in most satisfied fashion the surfaces of the not yet open female flowers and, added to these, ants crawling busily over all. Although honey bees are plentiful on Fanning Island, they do not frequent the inflorescences to any marked degree. It should be stated here that too intimate contact with the "coconut beetles" is not advisable, since severe blistering will surely result. The darker species [*Sessinia* (*Anaca*) *collaris* (Sharp)], at least, probably breeds in rotting wood, since one of us collected a pupa in rotting umbrella wood. It is unlikely that these voracious beetles actually cause serious reduction in the amount of pollen.

Bud rot.—Since bud rot is widely distributed, practically throughout the Tropics, and is generally regarded as a serious menace to the coconut industry, evidences of its presence on Fanning Island were immediately sought. Johnston [3] describes the disease as follows:

> The common name of the disease, bud rot, well describes its nature, for in its acute or advanced stages the bud of the tree, i. e., the growing point in the center of the crown, is affected by a vile-smelling soft rot which destroys all the younger tissues. At this stage most of the nuts have fallen, the lower leaves are turning yellow, and the middle folded and undeveloped leaves are dead and hang down between the still green surrounding leaves. Signs of the disease in its incipiency are (1) the falling of the immature nuts; (2) a staining of the opening flower spikes, partly or wholly, to a rich chocolate brown; and (3) the dying and bending over of the middle undeveloped leaves. When the nuts are being shed investigation reveals at the base of the affected spikes a dark-colored wet rot which spreads around the leaf sheaths, or strainers, as they are locally (Cuba) known. This rot appears as water-soaked areas which may reach a length of 15 or 20 centimeters on both the upper and lower surfaces of the bases of the leaves. This condition often penetrates the leaf bases to a depth of 2 centimeters or more, and the tissues involved in it swarm with bacteria. As the white tissues at the base of the leaf become old and green the water-soaked spots harden, and they may often be found in this condition on otherwise perfectly healthy trees * * *. The rot spreads from the base of one spike to another through the wet strainer. It is probable that insects carry the disease from one part to another since there may be one or more points of infection. Gradually all the spikes become affected and shed their nuts, and the leafstalks become so rotted at their bases that they are not able to maintain their natural position, but are pendent, often for a long time, or else fall off.
>
> If the infection starts in the central leaves the disease is apt to progress rapidly downward into the younger tissues, which it is very active in disintegrating, the vascular bundles being so soft as to allow the tissues to go entirely to pieces. In the center it may progress into the

[3] U. S. Dept. Agr. Bur. Plant Industry Bull. 228 (1912) 1–175.

trunk for a short distance and rot out the fundamental tissue leaving only the fibers which are too hard to be disintegrated. This rot has been found, exceptionally, as far as 1.5 meters under the heart of the bud, a hard outer shell being left around the central rotted portion. Usually the decay extends in the trunk under the bud for a distance of only 0.2 to 0.5 meters and never throughout its length * * *. The spread of this disease may be very rapid. It may occur year after year as only scattered cases in a grove, but frequently whole plantations may be affected in a short time. In such groves scores and scores of bare trunks may be seen, the crowns of which have rotted and blown off. There may be trees with the whole crown bent over and hanging downward, and others with three or four ragged leaves waving upright in the air and all the rest brown, broken, hanging down, and dead. In the midst of this desolation there are often some green-crowned trees retaining a few nuts, or still in good bearing. From two months to more than a year may elapse from the time of the infection of the tree to its destruction.

Trees that gave any appearance whatsoever of bud-rot symptoms were carefully examined; and, although no bacteriological examination was made, owing to lack of facilities, I believe it fairly safe to state that this disease has not made its appearance on Fanning Island. The above description of the disease should be of assistance in detecting its presence, and should it be found strenuous efforts should, of course, be put forth to curb it without delay. The following recommendations by Johnston (loc. cit.) will, no doubt, be of service. He states:

It is recommended, therefore, to cut down all badly diseased trees, at least trim the tops and set fire to them. All debris, fallen leaves, nuts, etc., should be removed so as to destroy any infected material and any breeding places for insects which might serve to transmit the disease * * *. These ordinary methods of sanitation, together with proper methods of cultivation, if carried out faithfully by the planters of a whole district, will reduce the loss by this disease to a minimum.

Sundry insects.—Many species of insects are more or less closely associated with the coco tree and the copra industry. A slender, coal-black weevil, *Oxydema fusiforme* Woll., measuring about a quarter of an inch in length, frequently occurs under the leaf sheaths, or "strainers," or in decaying splits, etc. So-called copra "bugs" (beetles), *Necrobia rufipes* Fabr., occur in vast numbers about the copra house and in neighboring buildings. The larvæ of these beetles breed as a rule in the old copra waste, but may also breed in the copra waiting to be shipped and may then cause some damage which, however, is usually regarded as slight. Several species of ants occur in great numbers on the trees. Old fallen nuts, particularly on Washington Island,

show numerous emergence holes of the shot-hole borer *Xyleborus confusus* Eich.

Diocalandra taitensis (Guerin), with which this report chiefly deals, is undoubtedly the most important pest attacking the coco palm on Fanning Island. The identity of this insect, which had been causing much concern to the owners of the island, was established the day following our arrival at English Harbour. Typical injury to the trees and the discovery of larvæ and adults at work proved the insect to be *Diocalandra taitensis* (Guerin), Plate 4, fig. 1, as previously reported in a letter by me to Mr. D. B. Crane, under date of January 21, 1924, in part as follows:

> * * * as you have stated in your proposed cablegram, the specimens are not *Rhyncophorus ferrugineus* Fabr., but *Calandra taitensis* Guerin * * *. The Calandra beetles (weevils), on the other hand, as identified from specimens submitted, require different treatment * * *. Just what method of control to use seems to me somewhat doubtful without more careful study of the life history and habits of the insect and other possible plant hosts.

This beetle enjoys a rather wide distribution among the islands of the South Seas. It was first described from Tahiti in 1840, by Guerin.[4] Swezey[5] (1920) reports one specimen of this species in a collection from Tutuila, Samoa, and he also reports its presence on the whole leeward coast of the Island of Hawaii. Concerning the work of this species, Swezey[6] states:

> Its larvæ feed in the edges of the lower part of the leaf stalk, and as it is the older leaves that are most often attacked, they are not significantly injurious to the trees. They, too, are likely to be more abundant in stubs of cut-off leaves.

Doane[7] made a study of the larval work of this species in the Society Islands, where he evidently considers it a more or less serious pest. He states:

> A still more serious damage is done where the larvæ attack the spikelets, killing them at the point of attack and working toward the base.

Specimens of this species were taken on Christmas Island, August 1 to 3, 1924, by Mr. Kirby, who has reported to me that the species is as abundant there as on Fanning, if not more so. Dr. L. S. Harrison, who accompanied the recruit-

[4] Iconographie du regne animal. Paris (1840) 171.
[5] Proc. Hawaiian Ent. Soc. 6 (1920) 333–335.
[6] Proc. Hawaiian Ent. Soc. 5 (1924) 385–393.
[7] Journ. Econ. Ent. 2 (1919) 220–223.

ing expedition to the Gilberts during the summer of 1924, reports the presence of this beetle (in June) on Abaiang Island, where he states it is fairly abundant. A very closely related species, *Diocalandra frumenti* F., also known as the "four-spotted coconut weevil" of the Philippine Islands (where it is common, as well as in the entire Indo-Malay region), although strikingly similar to *D. taitensis* in form, color, and size, is said by Banks [8] to occur "in the dead or decayed heart or the undeveloped leaves" and to attack "only dead trees of a very small size" and "found only in locations where others have preceded them and killed the trees; hence they are not in any sense a menace to the healthy tree." Mr. W. Schultze, of the Bureau of Science, Manila, in a letter to me under date of April 21, 1925, states, "It is mostly found on coconut, but a few times I have found it on sugar cane, on newly cut ratoon stools."

The isolation of Fanning and Washington Islands, particularly the latter, no doubt made these among the latest to become infested with *Diocalandra taitensis*. The introduction of this pest may, perhaps, be explained through the recruiting of labor from other islands where the beetle may have occurred for many years. Natives frequently take coconuts with them as food and drink on recruiting voyages; the nuts, together with mats and other articles made from fronds and other parts of the coco tree, might easily account for the introduction of the species, either as beetle or as grub. I observed this possibility during the process of loading the *Doris Crane* for a recent recruiting voyage, natives returning to the Gilberts having articles with them which might easily give ample opportunity for such transfer. In view of the fact that Fanning Island still enjoys freedom from many other serious pests, it would seem most desirable to exercise due precaution in recruiting enterprises.

The fact that the beetle is most abundant at English Harbour and near the Cable Station lends weight to our belief that it was first introduced at these points where contact with the outside world is made. Just how long the species has existed on this island is practically impossible to determine, but it has probably been here for at least eight or ten years, perhaps much longer. Aua and Tarafefe, the more remote camps, appear to have the least infestation. That the presence of the beetle was not even suspected until its discovery quite recently is due largely to the rather slow and subtle nature of the work of the insect and also

[8] Philip. Journ. Sci. 1 (1906) 143–167, pl. 1–10.

to the lack of careful inspection, no doubt thought to be unnecessary because of the general healthy appearance of the trees and the isolation of the island. These several factors combined enabled the beetle to gain a firm foothold before it was discovered. Furthermore, conditions now known to be due to the beetle larvæ were attributed to other causes, or else no explanation for the injury was attempted.

NATURE OF DAMAGE

The larva of *Diocalandra taitensis* (Guerin) is a typical borer, and enters the healthy tissue of the coco palm (apparently its only host plant), where it grows rather slowly, frequently burrowing from 1 to 1.5 inches deep into heavy fronds and often tunneling (very slowly) a distance of 5 to 6 inches before coming to rest for pupation near the surface or at a crevice produced by splitting or hacking. The position of the older larvæ is marked by twisted strings of dark brown frass and castings, by discoloration of the tissue, and exudations from the plant (Plate 7, fig. 1). When the larva tunnels near the surface of the frond or base of a spike its course can be traced by the blackened plant tissue. Infection of the frond is usually located along the edges of the midrib and at the base, frequently at the basal connection with the trunk and, less frequently, at the axils of the leaflets, when the frond soon presents a very ragged appearance, the leaflets turning yellow, and fractures result (Plate 5, fig. 2). The larvæ also attack the trunks of older trees from which we frequently took both larvæ and pupæ.

The greatest damage is done when the larvæ attack the spikelets or, more particularly, the base of the spike itself. Spikelets with female flowers or young nuts, when thus attacked, will not mature their fruit and, when the base of the spike is well bored (Plate 7, fig. 2), a total loss of all its nuts is generally certain. Deformed nuts, which soon drop off, will result from *Diocalandra* borings, as shown in Plate 5, fig. 3. Fifteen such deformed and totally worthless nuts on one spike are not infrequent. I have seen many trees which should have been in bearing, many spikes being present, yet they were entirely devoid of nuts, or burdened with deformed nuts, as shown in the figure, which on inspection showed the marks of the borer in every spike examined.

It must, of course, be recognized that the absence of nuts from a spike or the presence of malformed nuts may be the result of other causes as well, such as absence of female flowers,

non-pollenization, rats gnawing at spikelets, nutritional defects, etc.; but it is significant that bare spikes and deformed nuts are remarkably abundant between Napunaiaroa and the Cable Station and in the vicinity of English Harbour where *Diocalandra* is abundant and well established, while at Aua where the pest is uncommon practically no malformed nuts were seen. The latter statement holds good also for the vicinity of Tarafefe. Growers of long experience have expressed perplexity over the fact that often one side or parts of a tree may bear normal nuts while the other side or other parts bear nuts such as shown in the figure. If the trouble were to be found in a general nutritional obstruction then it would follow that all the nuts would be affected and the tree itself should show signs of unthriftiness. So far as our observations on Fanning are concerned, *Diocalandra* borings have generally been present in the spikes bearing either no nuts or bad nuts and either no borings or very slight in the good ones. In Plate 6, figs. 1 and 2, are shown two trees growing within 60 feet of each other, approximately of the same age, and equally thrifty in general appearance; yet, one is laden with nuts and shows no damage to the spikes, while the other is almost devoid of nuts, though spikes are present (all of which, so far as I could examine them, showed *Diocalandra* borings).

Borers also frequently attack very young nuts at the point of attachment, causing them to drop. Husks of older nuts are frequently bored, and I have seen traces of larvæ having burrowed completely through the husk and into the nut. Such attacks generally result in badly deformed nuts or in dehiscence.

As stated earlier in this paper, the borers appear not to attack (or at least to do so rarely) young trees under about 4 years of age, while trees from about 6 to 10 years old seem to suffer most, particularly trees just about beginning to bear. The old trees and their fruit appear to suffer but little damage from borer attack, although the insects are frequently present. I have taken several beetles from between the sheath and the base of badly bored and nutless spikes on a tree 50 feet high.

While I do not believe that *Diocalandra* will directly kill a tree of any age, I have seen trees that were beyond redemption due to a combination of *Diocalandra* and caterpillar attack, resulting in a badly twisted and dwarfed condition (Plate 6, fig. 3). Such trees should be cut down and burned without delay in order to destroy a prolific source or focus of pests, both borers and caterpillars. That young trees are weakened by

Diocalandra borings alone appears to be obvious, and that a marked reduction in nut production often results due to borings in spikes, spikelets, and young nuts is certain.

The burrowing of the borers also paves the way for bacterial and fungous attack which usually augments the damage. Conversely, also, wounds infected with bacteria and fungi offer acceptable points of attack for the beetles. For example, in cutting out larvæ from fronds, a practice quite generally employed, an injury results which quickly leads to a decay of the surrounding tissue, and it is in such situations that beetles may usually be found in due course of time, provided there is a crevice into which the insects can creep. Hence, if this practice is continued, the cut area should be treated immediately with a chemical which has both healing and repellent properties.

METHODS OF COLLECTING BEETLES

Beetles were rather easily collected in sufficient numbers for our purpose from coco palms in various parts of the island, but especially in an area between 1 and 3 miles southerly from English Harbour, where our temporary laboratory was located. In the area just mentioned there are many young bearing trees, and the percentage of *Diocalandra* infection is considerable. Infected trees could always be located easily by means of the dark strings of frass on the fronds, trunk, or other parts of the tree. Partly split, gashed, or otherwise injured fronds showed conspicuous darkened areas and generally served to locate beetles. By opening these split or gashed areas the beetles were exposed, and they were then carefully lifted off by means of forceps and placed in glass vials. The beetles adhere rather tightly to the tissue but when disturbed commonly let go and drop, feigning death. I have never seen them attempt to fly away while working with them in the field, although they crawl rapidly and disappear quickly in even very narrow crevices.

The beetles were taken to the laboratory and placed for breeding purposes in vials or pill boxes, the former being more satisfactory, because observations could be made more readily and eggs recovered more easily. In many instances pairs taken in copulation were placed in separate vials, while in several instances as many as twenty-five were placed in a vial. In each vial was placed a strip of coco-palm wood for the insects to feed upon. These strips were quickly punctured with holes. The vials were numbered and records were kept for each on numbered library cards. Observations were made from three to

four times daily until the death of the beetles. Eggs were found either on the walls of the vials or on the strips of wood, and they were transferred by means of a camel's-hair brush to separate vials and each was given a separate number which was recorded on the card of the parent. When the larvæ hatched they were likewise transferred to a slit in a cross section or block of a young coco frond; each block was about 2.5 inches long, about 1 inch thick, and about 1.5 inches broad. The larvæ generally quickly concealed themselves in these slits and soon began burrowing from sight. The infected coco blocks were numbered to correspond to the number given the egg, and were then placed with other blocks in a fruit jar. In order to observe early developments several larvæ were placed on rather small coco strips from which the grubs could be easily recovered by splitting the strips.

In order to observe pupation practically full-grown larvæ were extracted from infected fronds in the field and transferred to a pit cut into a small block of coco-palm wood. The block with the larva was placed in a vial and the pit covered with another block of coco-palm wood. Generally in an hour, more or less, the grub had covered itself with borings and began burrowing in the block, where eventually it pupated. In order to follow developments it was necessary to split the block every two or three days.

Pupæ were also collected in the field by carefully removing enough of the surrounding wood with a knife so as not to disturb or injure the pupa. The blocks were taken to the laboratory and placed in pill boxes where observations could be readily made. Pupæ removed from the trees without some of the surrounding wood and placed in pill boxes almost invariably died.

Egg.—The eggs are nearly a millimeter in length, slender, and well rounded at both ends (Plate 4, fig. 4). When first laid they are pearly white in appearance, becoming somewhat milky white as incubation proceeds. I have taken the eggs in the field in various situations where the adult beetles found good harborage, a good location being in the crevice of a more or less split coco frond, where decay has already set in, or under the strainer at the base of an old frond, also between the sheath and base of the spike. The eggs are apparently frequently deposited in scattered masses ranging from eleven to thirty-one and, more frequently, singly. The number of eggs deposited by the individual female beetle was not ascertained; however, the

number deposited under experimental conditions in the laboratory was never large, ranging from two to four, even by females newly emerged from the pupa and mated. Presumably the number laid in nature may be represented by the number taken in egg clusters, although that point also is difficult to determine, since the adults frequently occur in groups (as many as ten or twelve) always protected, of course, in a crevice or under the strainer folded over the edges of the frond.

Under temperature conditions already described the incubation period varies from four and a half to eight and a half days. Movements of the embryo can easily be seen through the egg shell twenty-four hours prior to hatching.

Larva.—The newly hatched larvæ are rather active, which enables them to crawl some distance. In laboratory experiments I have found that the larvæ do not readily attack smooth, tough frond tissue, but find lodgment in small cuts or pits produced by the gnawing beetles, which openings they enter and soon begin to burrow. Nevertheless, the heavy, otherwise unblemished base of the coco frond, particularly along the fibrous edges, presents a favorite location for the larvæ, as do the axils of the leaflets. After penetration, growth is very slow and observation then becomes almost impossible. Older larvæ can be cut out from the tree and transferred to small blocks from coco fronds, into which pits are cut with a knife and the larvæ introduced. The larva soon burrows and covers the hole with tiny shreds and continues its development. By placing such a block in a small vial to protect the larva against ants, observations can be made from time to time by splitting open the block to expose the larva for examination and then quickly closing it again to prevent too much disturbance. This method of observation, to be sure, cannot be relied upon to give accurate information relative to rate of larval growth. The time covered by the investigation was not long enough to determine the length of the larval period accurately. From a combination of evidence, both field and laboratory, it would appear that the larval stage requires from eight to ten weeks. Two larvæ that appeared to be about full grown were treated as above described on May 19, 1924, and did not pupate until June 21 and 22, 1924. Opening the block of coco wood at intervals of about three days, no doubt, greatly disturbed the larvæ, as evidenced by the new frass or repaired protective cases produced each time after examination. However, undisturbed checks appeared to

develop with about equal slowness. The full-grown larva (Plate 4, fig. 2) is cream colored and rather plump, and measures from 9 to 10 millimeters in length.

Pupa.—The full-grown larva comes finally to rest in an enlarged burrow near the surface, not necessarily at the surface, which it lines with finely cut borings (frass), producing a crude capsule (Plate 4. fig. 3). In a remarkably short time the larva takes on pupal form, showing the proboscis, appendages, and general outlines of the imago with remarkable clearness (Plate 4, fig. 2). The color of the pupa remains shining white to cream color until about time for emergence, when it darkens somewhat, not really taking on the rusty red markings and general color of the adult until it has actually emerged from its cell. I have taken pupæ from many parts of the coco tree, including particularly the edges of old fronds and axils of leaflets, also from the bases of spikes and spikelets. Ten to twelve days are required for the pupal period. Thus the time required to complete the life history of the species (egg to emergence of imago) appears to be from ten to twelve weeks.

Adult.—The adults are rather easily collected by picking them off the wood by means of fine-pointed forceps. They hold on rather firmly but when disturbed usually roll off, feigning death. They apparently do not normally use their wings, being able to crawl rapidly. I have allowed the beetles to crawl on the table and but rarely have I seen them try their wings and then only with remarkably little success, the insects progressing with a sort of hop and weak use of the wings for but a few inches.

The adults can use their proboscides remarkably well, literally chewing holes through coco strips which were placed in vials to serve as food and as a place for egg attachment. Eggs are frequently deposited in the crevices of the pitted wood, although I have more frequently found the eggs attached to the walls of the glass vials containing the beetles. The beetles remain in one position for hours at a time, gradually chewing a hole (pit) in the strip. The head is rocked from side to side as the insect chews.

Males often engage in a veritable rough-and-tumble conflict, butting each other about like rams for the possession of a female. When paired they may remain in copulation literally for hours at a time. The adult insect is a small, narrow weevil, measuring somewhat over one-quarter inch (7 millimeters) in length. It is pitchy black in ground color with reddish yellow

legs; there are clouded markings on the thorax, and the wing covers vary from practically all red to red with six black spots or markings, two basal, two median, and two apical. The head and beak are about half the length of the thorax, or one-fifth the entire length of the insect.

DIOCALANDRA ON WASHINGTON ISLAND

As already stated, the cocos on Washington Island are nearly all wild, and most of them are fairly old, except some planted near headquarters. This planting near headquarters, and as far inland as a large surveyor's block, was inspected for beetle injury both morning and afternoon of the day following our arrival on Washington Island, May 14. My note book record states "*Calandra* work seems to be scarce." Comparatively few trees showed typical frass; very few larvæ and no beetles were found. On the day following (May 15) a trip was made with Major Burn-Callander by boat through the canal to Monouou where such trees were examined as could be reached, and no trace of beetle work was seen at that end of the island. Other trips were made to beyond the northerly end of track, both along the beach and inland, and again few traces of beetle injury could be found. That this beetle has already established itself on Washington Island is certain, but it is at present causing very little or no damage. There is no reason to believe that the life history and habits of the beetles on Washington Island differ from those of Fanning Island; hence, facts ascertained at the latter place should apply with equal force to the former.

CONTROL MEASURES

From the general nature of the coco tree and the habits of the insect pest, it becomes obvious that the usual methods of insect control cannot be employed economically or are totally impracticable. Thus, fumigation as employed in citrus orchards against scale insects is out of the question, and spraying as employed, for example, against the codling moth of apples is almost equally unthinkable. The first suggestion that seems fairly reasonable is the removal of the borers by cutting out infected parts or by elimination of complete fronds. It has already been pointed out that the parts thus injured become very attractive to beetles in time, hence the need of applying a chemical, such as carbolineum, to produce rapid healing of the wound and also to act as a repellent against the insect. This method of control also calls for a further precaution; namely, expeditious destruction of the removed part, because, unless the

removed portion is very small, indeed, thus drying up in short order, the larvæ will continue their development through pupation to emergence of adults. This I have repeatedly observed, particularly where large parts of fronds have been lopped off and either allowed to remain where they had fallen or removed to a heap of rubbish. These parts must be burned within a short time after removal. A month's time will not allow many of the insects to complete their development and will permit a little time for drying.

Frequent systematic inspection of all trees up to 10 or 12 years of age should be practiced, so that badly infested trees may be located and given particular attention; or, if too far gone and a prolific source of pests, which is usually the case, they should be chopped down and burned without delay.

Natural enemies of *Diocalandra* on Fanning Island seem to be entirely absent, at least so far as our observations are concerned. In our breeding and life-history experiments hundreds of beetles, numerous pupæ and larvæ, and many eggs were kept for adequately long periods in vials, pill boxes, fruit jars, and other receptacles, and always a careful watch was kept for parasites, but none was observed. Because of the difficulty in controlling this species by so-called artificial means, biological control through the agency of natural enemies seems particularly desirable. This method of control is successfully practiced in parts of California against certain citrus pests, notably the soft brown scale (*Coccus hesperidum* Linn.), which is controlled by means of certain species of very tiny wasps (*Aphycus* sp.), and the cottony cushion scale (*Icerya purchasi* Mask.), controlled by its natural enemies, the ladybird beetles [*Novius cardinalis* (Muls.) and *N. koebelei* (Olliff)].

In the introduction of pests to a new locality, entrance is frequently made without their natural controlling factor that makes the same species comparatively or quite innocuous in their native habitat. The United States Department of Agriculture through its Bureau of Entomology has entomologists stationed in Japan at present, in order to find a parasite to combat the destructive Japanese beetle (*Popillia japonica* Newn.) which, while of little consequence in Japan, is most damaging in an ever-increasing area in the eastern United States. This investigation I am informed is giving very hopeful results. Thus it would appear that *Diocalandra taitensis* (Guerin) must exist somewhere under conditions where it is held in check by its natural enemies; these might perhaps be reared

in sufficient quantities to be introduced on both Fanning and Washington Islands and, by gaining a foothold there, would eventually bring the beetle pest under practical control.

SUMMARY

1. Both Fanning and Washington Islands are so situated geographically and commercially that it should be difficult for pests to gain entrance except through the company's own transportation and infrequent steamer communication (by lighter and launch) at the Pacific Cable Station at Fanning. With the increasing necessity for precaution in the face of the growing importance of pests, greater care is urged in inspecting cargo, particularly that from the South Seas (inclusive of the personal effects of recruited laborers), in order to forestall further introduction of pests and diseases of the coco palm to these islands, which are even yet free from many of the worst pests that have fairly ravished many plantations in other parts of the world. In this matter the Pacific Cable Board would without question render hearty coöperation.

2. The total annual rainfall for Fanning Island is indicated by the records for the following years: 1918 (to December 20), 102.76 inches; 1922, 59.32 inches; 1923, 66.41 inches; and for the first eight months of 1924, 55.38 inches. Although June to October are regarded as the drier months, the rains are fairly evenly distributed during the year. While Fanning Island lies on the edge of a rain belt, Washington Island is nearer the middle of this belt and consequently enjoys a heavier rainfall. The temperature on Fanning Island is remarkably equable throughout the year, the maximum being 93° F., which is rarely reached, 85° F. being the usual maximum, while 70° F. is the minimum, which also is rarely reached, 78° F. being the usual minimum. Cooling trade winds play an important part in making these islands fairly comfortable. The temperature of Washington Island is much the same as that of Fanning, but with its heavier rainfall and vegetation it presents a much more tropical atmosphere. The relative humidity of Fanning Island ranged from 72 to 76, inclusive, during the months of May to July, the period of our stay. Washington Island humidity readings on four days during May ranged from 71 to 77, inclusive.

3. The coco plantations of Fanning Island comprise about 3,200 acres, of which about one-third is in wild trees. The trees in general present a fairly healthy appearance, although many of them of bearing age in certain localities have not begun

to bear owing to extreme retardation by choking umbrella, buka, and nashu brush, now largely cut and piled waiting to be burned; while other trees, though thrifty in appearance, bear many deformed nuts or shed them while still young. Collections of rubbish are conspicuously present in some parts of the island, and these afford a most favorable harborage for rats and other vermin and would certainly prove disadvantageous should certain other pests which breed in decaying rubbish and not now present be unfortunately introduced. This defect is being rapidly remedied.

4. The Washington Island plantation (uncultivated for about one and a half years) comprises about 2,100 acres of coco trees, of which about 200 acres are planted. The wild trees have grown up entirely too close together, and there are sprouting nuts, much tangled and rank undergrowth, and bog in many places, all of which present nutting and other difficulties of some importance, though not within the scope of this investigation.

5. Burning piles of brush among the rows of trees, while unavoidable, has resulted in severe temporary injury to many young trees; however, with relatively few exceptions, these have revived. Removal of brush from among the badly choked trees was imperative and, in order to carry out ordinary plantation sanitation and eliminate future nutting difficulties, destruction of this brush by fire is necessary; to drag the brush to free areas there to be burned would entail prohibitive expense. Great care and judgment must be exercised in burning the brush. Future methods of planting and cultivation will, of course, be guided by past error in judgment.

6. Pests of the coco palm on Fanning and Washington Islands are rats (*Epimys alexandrinus*), which gnaw young nuts and the bases of spikelets; robber crabs (*Birgus latro*), almost extinct on Fanning; white scale (*Hemichionaspis aspidistrae*), well parasitized by *Aspidiotiphagus citrinus;* mealy bugs (*Pseudococcus pandani*), not abundant; caterpillars, belonging to two species not identified, particularly damaging to very young trees; *Xyleborus confusus,* a shot-hole borer, in old fallen nuts in particular; and the lesser coconut borer (*Diocalandra taitensis*), the most important of all.

7. The larva of *Diocalandra taitensis* bores into the healthy plant tissue, attacking fronds, trunks, spikes, spikelets, and young nuts. Trees from about 3 years of age to very old ones are attacked by the beetles, the greatest amount of damage being done to trees which have recently come into bearing,

and here the damage consists primarily in the loss of nuts through bored spikes and spikelets. A combined *Diocalandra* and caterpillar attack will cause young trees to become badly twisted and stunted, and death may ensue.

8. The beetle lays its eggs in crevices in split or otherwise injured fronds, or between the strainer and the edge of the frond, and between the sheath and the base of the spike. Although only from two to five eggs are deposited by the female beetle in the laboratory, egg masses of eleven to thirty-one eggs have been taken in the field, but in the presence of groups of females. The incubation period is from four and one-half to eight and one-half days. The young borers are very active and are soon lost from sight, as they burrow into slight abrasions or among the hairs of the fronds or, in fact, almost any place that offers a favorable point of entrance. There is a marked preference for healthy tissue.

9. Based on cumulative fragmentary evidence, both in the field and in the laboratory, it appears reasonably certain that the larval period requires from eight to ten weeks, by the end of which time the full-grown larva has burrowed fairly close to the surface where the plant tissue has by this time become fairly well decayed by the working of the larva, and there it constructs a crude case of castings and borings and then pupates.

10. The pupal period can be rather easily ascertained by allowing larvæ to pupate in small blocks of coco wood in the laboratory. From ten to twelve days are required to complete this period. Thus the entire life history of *Diocalandra taitensis* requires approximately from ten to twelve weeks.

11. That it would be easy to transport this species long distances is evidenced by the fact that, on May 19, a well-advanced larva was placed in a block of coco-palm wood measuring about a half inch square; it pupated in this same piece June 22, and emerged as an adult beetle on July 3. In the meantime, in order to observe developments, the block had been split open numerous times and afterward tied together again with thread. Another similar experiment, conducted simultaneously, gave like results.

12. The usual methods of insect control cannot be applied economically. Frequent inspection of all trees up to 10 or 12 years of age is strongly recommended. Badly infested young trees (3 to 5 years of age), if twisted and dwarfed, form a center of distribution, and they should be cut down and burned without delay. Badly infested fronds should be cut and burned;

the remaining cut portion should be treated with an effective healing and repellent chemical.

13. The beetle infestation on Washington Island is comparatively light and, with the exercise of good judgment in the application of control measures, might be rather easily prevented from spreading and perhaps wholly smothered.

14. It is strongly recommended that a determined effort be made to locate a parasite that will prey effectively on *Diocalandra taitensis*, preferably on either the egg or the adult.

ILLUSTRATIONS

PLATE 1

FIG. 1. A dense thicket on Washington Island. Fallen and sprouting coconuts add greatly to nutting difficulties.

2. *Hemichionaspis aspidistrae* Signoret, greatly enlarged, showing both male (fluted) and female (large ovoid) scales.

PLATE 2

FIG. 1. Coco palms said to be from 8 to 9 years of age, badly retarded in growth due to choking bush now cut and ready to be burned. Compare with fig. 2.

2. Coco palms only 2.5 to 4 years of age, free from choking bush. Compare with fig. 1.

3. Young coco palms damaged by fire. Unless the damage is too severe, recovery is rapid.

PLATE 3

FIG. 1. Burning brush between rows of coco palms and method of protecting young trees with cut fronds.

2. Young coconuts damaged by rats.

PLATE 4

FIG. 1. The Tahiti coconut borer, *Diocalandra taitensis* (Guerin); adults.

2. *Diocalandra taitensis* (Guerin), larvæ and pupa.

3. *Diocalandra taitensis* (Guerin), adult in pupal cell. The case is split open to show its construction.

4. *Diocalandra taitensis* (Guerin), eggs.

PLATE 5

FIG. 1. Fronds of coco palm damaged by caterpillars. Note crinkling of leaflets.

2. Infestation of the frond is usually located along the edges of the midrib and at the base, frequently at the basal connection with the trunk and less frequently at the axils of the leaflets when the frond soon presents a very ragged appearance; the leaflets turn yellow and fractures result.

3. The greatest damage is done to a coco palm when the larvæ of the coconut borer attack the spikelets or more particularly the base of the spike itself, which when well bored will result in deformed nuts and eventually a total loss of all its fruit.

PLATE 6

FIG. 1. A vigorous young coco palm well laden with nuts; the spikes are free from beetle borings or only slightly attacked.

2. A young coco palm in a row adjacent to the tree shown in fig. 1 is entirely devoid of nuts. Every spike shows *Diocalandra* borings; otherwise the tree is in good condition.

3. A young coco palm badly bored by *Diocalandra*. Such a tree is a prolific center of distribution and should be cut and burned.

PLATE 7

FIG. 1. Larval borings of *Diocalandra taitensis* (Guerin) in midrib of fronds. Note frass and discoloration.

2. Segments near base of coconut spikes showing borings of larval *Diocalandra*. This damage to the spike when bearing young nuts prevents proper nourishment and results in deformed fruit and dropping.

PLATE 8

The coconut crab, *Birgus latro* Herbst, showing enormous size of powerful pincers.

TEXT FIGURES

FIG. 1. Map of Fanning Island, Pacific Ocean; 3° 51′ 26″ north, 159° 22′ west. (Drawn by Robt. O'Neal, Honolulu.)

2. Map of Washington Island, Pacific Ocean; 4° 41′ 10″ north, 160° 19′ west. (Drawn by Robt. O'Neal, Honolulu.)

3. Thermograph records from Fanning Island for two weeks, June 16 to 22, inclusive, and July 21 to 27, inclusive, 1924, showing remarkable daily uniformity.

1

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PLATE 1.

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PLATE 2.

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PLATE 3.

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PLATE 4.

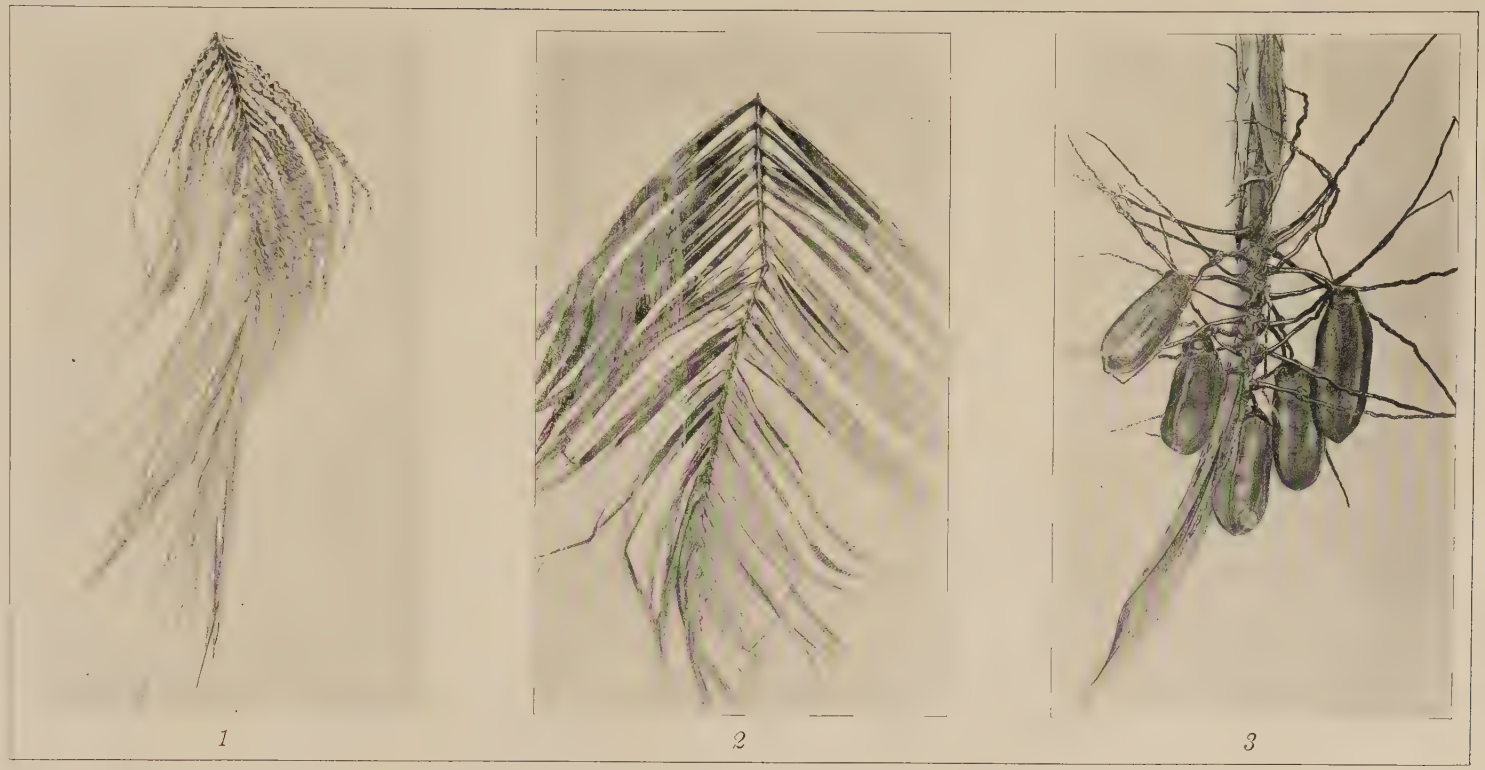

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PLATE 5.

1 2 3

PLATE 6.

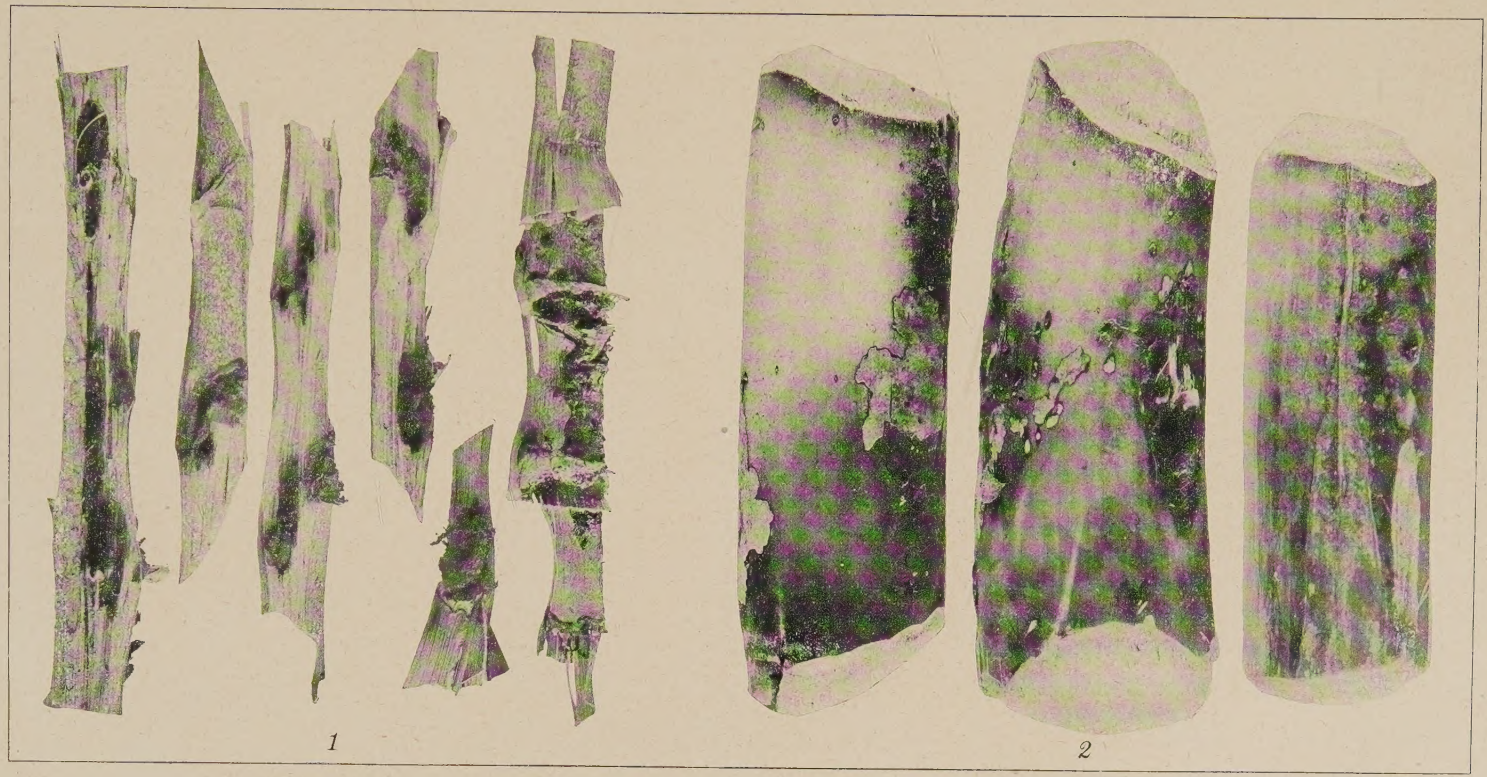

PLATE 7.

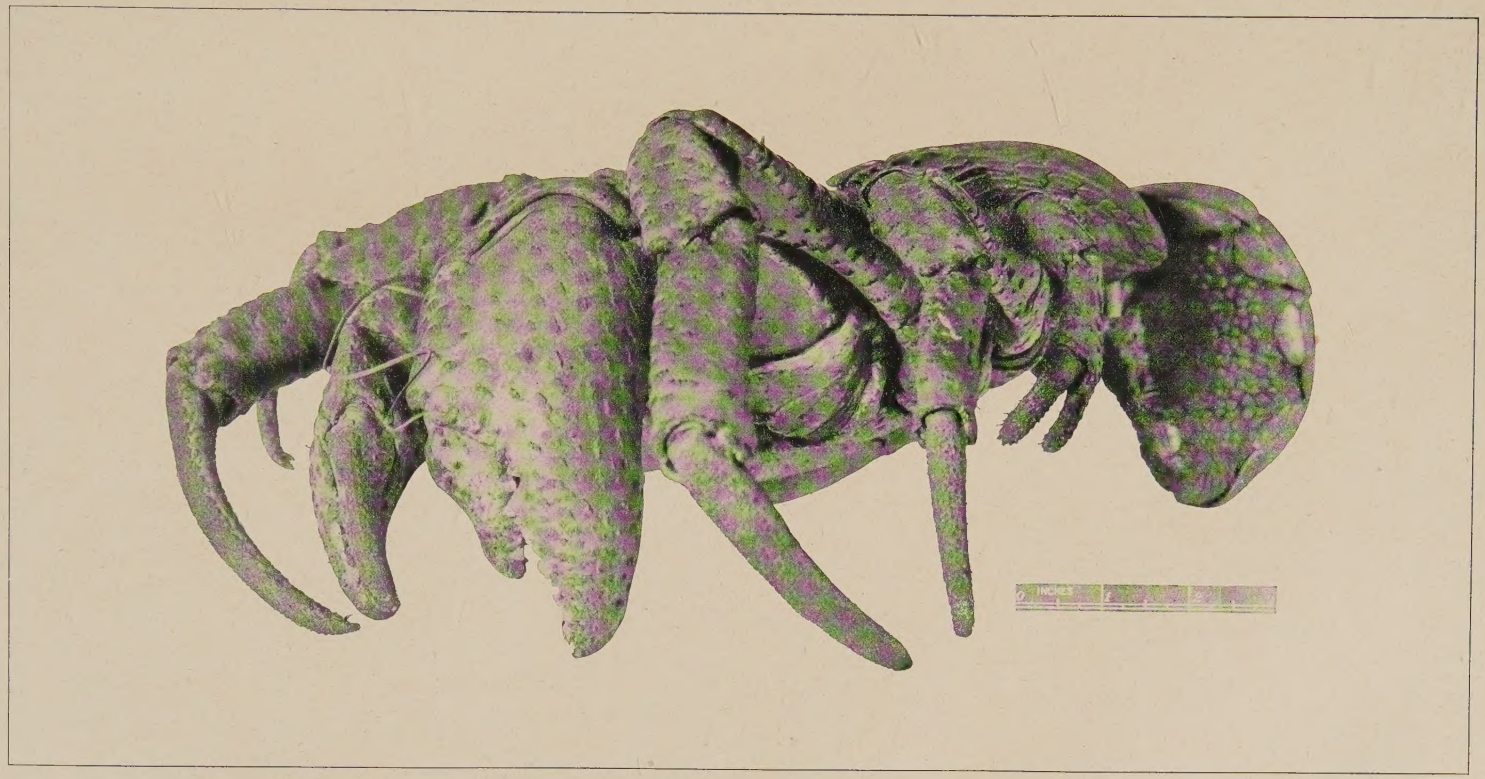

PLATE 8.